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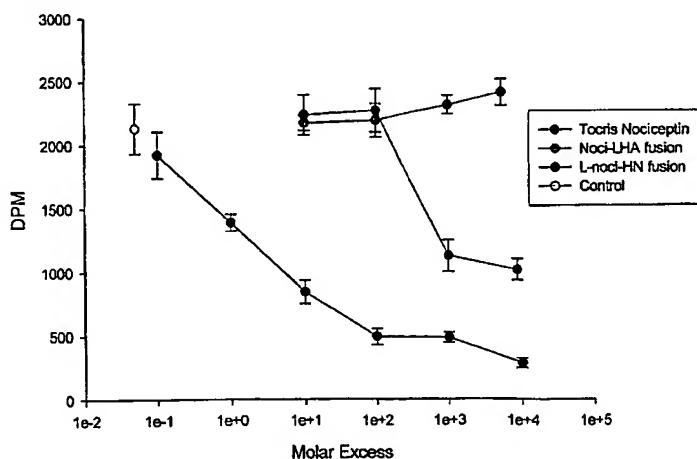
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(54) Title: TREATMENT OF PAIN

Competition Assay : Nociceptin-LH₄/A Fusions
vs 1nM [³H]-Nociceptin on eDRGs (4°C)

(57) Abstract: Use of a therapeutic molecule for the manufacture of a medicament for the treatment of a particular type of pain, wherein the therapeutic molecule comprises a non-cytotoxic protein conjugate that binds to a nociceptive sensory afferent cell, and comprises: (i) a Targeting Moiety (TM), wherein said TM is an agonist of a receptor present on said nociceptive sensory afferent cell, and wherein said receptor undergoes endocytosis to be incorporated into an endosome within the nociceptive sensory afferent cell; (ii) a non-cytotoxic protease or a fragment thereof, wherein the protease or protease fragment is capable of cleaving a protein of the exocytic fusion apparatus of said nociceptive sensory afferent cell; and (iii) a Translocation Domain, wherein the Translocation Domain translocates the protease or protease fragment from within the endosome, across the endosomal membrane, and into the cytosol of the nociceptive sensory afferent cell.

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Treatment of pain

This invention relates to the use of non-cytotoxic protein conjugates for the treatment of specific types of pain.

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Toxins may be generally divided into two groups according to the type of effect that they have on a target cell. In more detail, the first group of toxins kill their natural target cells, and are therefore known as cytotoxic toxin molecules. This group of toxins is exemplified *inter alia* by plant toxins such as ricin, and abrin, and by
10 bacterial toxins such as diphtheria toxin, and *Pseudomonas* exotoxin A. Cytotoxic toxins typically kill their target cells by inhibiting the cellular process of protein synthesis.

15

In contrast, the second group of toxins, which are known as non-cytotoxic toxins, do not (as their name confirms) kill their natural target cells. Non-cytotoxic toxins have attracted much less commercial interest than have their cytotoxic counterparts, and exert their effects on a target cell by inhibiting cellular processes other than protein synthesis. As with their cytotoxic counterparts, non-cytotoxic toxins are produced from a variety of sources such as plants, and bacteria. Bacterial non-cytotoxic toxins
20 are now described in more detail.

25

Clostridial neurotoxins are proteins that typically have a molecular mass of the order of 150 kDa. They are produced by various species of bacteria, especially of the genus *Clostridium*, most importantly *C. tetani* and several strains of *C. botulinum*, *C. butyricum* and *C. argentinense*. There are at present eight different classes of the clostridial neurotoxin, namely: tetanus toxin, and botulinum neurotoxin in its serotypes A, B, C₁, D, E, F and G, and they all share similar structures and modes of action.

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Clostridial neurotoxins represent a major group of non-cytotoxic toxin molecules, and are synthesised by the host bacterium as single polypeptides that are modified post-

translationally by a proteolytic cleavage event to form two polypeptide chains joined together by a disulphide bond. The two chains are termed the heavy chain (H-chain), which has a molecular mass of approximately 100 kDa, and the light chain (L-chain), which has a molecular mass of approximately 50 kDa.

5

L-chains possess a protease function (zinc-dependent endopeptidase activity) and exhibit high substrate specificity for vesicle and/or plasma membrane associated proteins involved in the exocytic process. L-chains from different clostridial species or serotypes may hydrolyse different but specific peptide bonds in one of three
10 substrate proteins, namely synaptobrevin, syntaxin or SNAP-25. These substrates are important components of the neurosecretory machinery.

Non-cytotoxic toxins are also produced by other bacteria, such as from the genus *Neisseria*, most importantly from the species *N. gonorrhoeae*. For example,
15 *Neisseria* sp. produces the non-cytotoxic toxin IgA protease (see WO99/58571).

It has been well documented in the art that toxin molecules may be re-targeted to a cell that is not the toxin's natural target cell. When so re-targeted, the modified toxin is capable of binding to a desired target cell and, following subsequent translocation
20 into the cytosol, is capable of exerting its effect on the target cell. Said re-targeting is achieved by replacing the natural Targeting Moiety (TM) of the toxin with a different TM. In this regard, the TM is selected so that it will bind to a desired target cell, and allow subsequent passage of the modified toxin into an endosome within the target cell. The modified toxin also comprises a translocation domain to enable
25 entry of the non-cytotoxic protease into the cell cytosol. The translocation domain can be the natural translocation domain of the toxin or it can be a different translocation domain obtained from a microbial protein with translocation activity.

For example, in the context of non-cytotoxic toxin molecules, it has been well
30 documented that a clostridial neurotoxin may be re-targeted by incorporation of a Targeting Moiety (TM), which is not the natural TM of a clostridial neurotoxin. The described chemical conjugation and recombinant methodologies are now regarded

as conventional, and reference is made to Hermanson, G.T. (1996), Bioconjugate techniques, Academic Press, and to Wong, S.S. (1991), Chemistry of protein conjugation and cross-linking, CRC Press.

5 Thus, from the above-described publications, it will be appreciated that the basic concept of re-targeting a non-cytotoxic protease to a desired target cell, by selecting a TM that has a corresponding receptor present on the target cell, has been well documented.

10 However, different receptors present on a target cell of interest demonstrate different binding affinities for different TMs. This may be a particular problem with pain-sensing cells, which possess a wide range of receptor types having different binding affinities for different TMs. Thus, a re-targeted conjugate comprising a particular TM may demonstrate only a low binding affinity for a pain-sensing target cell, which is
15 undesirable.

There is therefore a need to develop modified non-cytotoxic conjugates that address one or more of the above problems. Of particular interest is the development of an improved conjugate for use in the treatment of particular types of pain.

20

The present invention seeks to address one or more of the above problems by using as the conjugate's Targeting Moiety (TM) an "agonist" of a receptor that is present on the pain-sensing target cell of interest. In preferred embodiments, the pain-sensing target cell is a nociceptive sensory afferent, more preferably a primary
25 nociceptive sensory afferent. In particularly preferred embodiments, the TM is an agonist of the opioid-like receptor-1 (ORL₁) receptor.

Accordingly, in a first aspect, the present invention provides use of a therapeutic molecule for the manufacture of a medicament for the treatment of a particular type
30 of pain, wherein the therapeutic molecule is a non-cytotoxic protein conjugate that binds to a nociceptive sensory afferent cell, and comprises:

- (i) a Targeting Moiety (TM),

wherein said TM is an agonist of a receptor present on said nociceptive sensory afferent cell, and wherein said receptor undergoes endocytosis to be incorporated into an endosome within the nociceptive sensory afferent cell;

- (ii) a non-cytotoxic protease or a fragment thereof,

wherein the protease or protease fragment is capable of cleaving a protein of the exocytic fusion apparatus of said nociceptive sensory afferent cell; and

- (iii) a Translocation Domain,

wherein the Translocation Domain translocates the protease or protease fragment from within the endosome, across the endosomal membrane, and into the cytosol of the nociceptive sensory afferent cell.

The use of an "agonist", which would normally stimulate a biological process, particularly exocytosis (for example, an increase in cellular secretion, or an up-regulation in membrane protein expression), is an exciting development in the technical field of re-targeted toxins. Furthermore, it is particularly surprising that an agonist may be employed in a therapeutic composition to achieve a reduction or inhibition of a biological process that the agonist would normally stimulate.

The agonist-containing conjugates of the present invention represent a distinct subset of toxin conjugates. In more detail, the conjugates of the present invention comprise TMs that have been selected on the basis of specific agonist properties rather than on the simple basis that they have a corresponding receptor on a pain-sensing target cell of interest.

The compounds described here may be used to treat a patient suffering from one or more types of chronic pain including neuropathic pain, inflammatory pain, headache pain, somatic pain, visceral pain, and referred pain.

5

To "treat," as used here, means to deal with medically. It includes, for example, administering a compound of the invention to prevent pain or to lessen its severity.

The term "pain," as used here, means any unpleasant sensory experience, usually associated with a physical disorder. The physical disorder may or may not be apparent to a clinician. Pain is of two types: chronic and acute. An "acute pain" is a pain of short duration having a sudden onset. One type of acute pain, for example, is cutaneous pain felt on injury to the skin or other superficial tissues, such as caused by a cut or a burn. Cutaneous nociceptors terminate just below the skin, and due to the high concentration of nerve endings, produce a well-defined, localized pain of short duration. "Chronic pain" is a pain other than an acute pain. Chronic pain includes neuropathic pain, inflammatory pain, headache pain, somatic pain visceral pain and referred pain.

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1. Neuropathic Pain

The compounds of the invention may be used to treat pain caused by or otherwise associated with any of the following neuropathic pain conditions. "Neuropathic pain" means abnormal sensory input, resulting in discomfort, from the peripheral nervous system, central nervous systems, or both.

25

A. Symptoms of neuropathic pain

Symptoms of neuropathic pain can involve persistent, spontaneous pain, as well as allodynia (a painful response to a stimulus that normally is not painful), hyperalgesia (an accentuated response to a painful stimulus that usually causes only a mild discomfort, such as a pin prick), or hyperpathia (where a short discomfort becomes a prolonged severe pain).

30

B. Causes of neuropathic pain

Neuropathic pain may be caused by any of the following.

1. A traumatic insult, such as, for example, a nerve compression injury (e.g., a nerve crush, a nerve stretch, a nerve entrapment or an incomplete nerve transection); a spinal cord injury (e.g., a hemisection of the spinal cord); a limb amputation; a contusion; an inflammation (e.g., an inflammation of the spinal cord); or a surgical procedure.
2. An ischemic event, including, for example, a stroke and heart attack.
3. An infectious agent
- 10 4. Exposure to a toxic agent, including, for example, a drug, an alcohol, a heavy metal (e.g., lead, arsenic, mercury), an industrial agent (e.g., a solvent, fumes from a glue) or nitrous oxide.
5. A disease, including, for example, an inflammatory disorder, a neoplastic tumor, an acquired immune deficiency syndrome (AIDS), Lyme disease, a leprosy, a metabolic disease, a peripheral nerve disorder, like neuroma, a mononeuropathy or
15 a polyneuropathy.

C. Types of neuropathic pain

1. Neuralgia.

- 20 A neuralgia is a pain that radiates along the course of one or more specific nerves usually without any demonstrable pathological change in the nerve structure. The causes of neuralgia are varied. Chemical irritation, inflammation, trauma (including surgery), compression by nearby structures (for instance, tumors), and infections may all lead to neuralgia. In many cases, however, the cause is unknown or
25 unidentifiable. Neuralgia is most common in elderly persons, but it may occur at any age. A neuralgia, includes, without limitation, a trigeminal neuralgia, a post-herpetic neuralgia, a postherpetic neuralgia, a glossopharyngeal neuralgia, a sciatica and an atypical facial pain.

- 30 Neuralgia is pain in the distribution of a nerve or nerves. Examples are trigeminal neuralgia, atypical facial pain, and postherpetic neuralgia (caused by shingles or herpes). The affected nerves are responsible for sensing touch, temperature and

pressure in the facial area from the jaw to the forehead. The disorder generally causes short episodes of excruciating pain, usually for less than two minutes and on only one side of the face. The pain can be described in a variety of ways such as "stabbing," "sharp," "like lightning," "burning," and even "itchy". In the atypical form of
5 TN, the pain can also present as severe or merely aching and last for extended periods. The pain associated with TN is recognized as one the most excruciating pains that can be experienced.

Simple stimuli such as eating, talking, washing the face, or any light touch or
10 sensation can trigger an attack (even the sensation of a gentle breeze). The attacks can occur in clusters or as an isolated attack.

Symptoms include sharp, stabbing pain or constant, burning pain located anywhere, usually on or near the surface of the body, in the same location for each episode;
15 pain along the path of a specific nerve; impaired function of affected body part due to pain, or muscle weakness due to concomitant motor nerve damage; increased sensitivity of the skin or numbness of the affected skin area (feeling similar to a local anesthetic such as a Novacaine shot); and any touch or pressure is interpreted as pain. Movement may also be painful.

20

Trigeminal neuralgia is the most common form of neuralgia. It affects the main sensory nerve of the face, the trigeminal nerve ("trigeminal" literally means "three origins", referring to the division of the nerve into 3 branches). This condition involves sudden and short attacks of severe pain on the side of the face, along the
25 area supplied by the trigeminal nerve on that side. The pain attacks may be severe enough to cause a facial grimace, which is classically referred to as a painful tic (tic douloureux). Sometimes, the cause of trigeminal neuralgia is a blood vessel or small tumor pressing on the nerve. Disorders such as multiple sclerosis (an inflammatory disease affecting the brain and spinal cord), certain forms of arthritis,
30 and diabetes (high blood sugar) may also cause trigeminal neuralgia, but a cause is not always identified. In this condition, certain movements such as chewing, talking, swallowing, or touching an area of the face may trigger a spasm of excruciating pain.

A related but rather uncommon neuralgia affects the glosso-pharyngeal nerve, which provides sensation to the throat. Symptoms of this neuralgia are short, shock-like episodes of pain located in the throat.

5

Neuralgia may occur after infections such as shingles, which is caused by the varicella-zoster virus, a type of herpesvirus. This neuralgia produces a constant burning pain after the shingles rash has healed. The pain is worsened by movement of or contact with the affected area. Not all of those diagnosed with shingles go on to experience postherpetic neuralgia, which can be more painful than shingles. The pain and sensitivity can last for months or even years. The pain is usually in the form of an intolerable sensitivity to any touch but especially light touch. Postherpetic neuralgia is not restricted to the face; it can occur anywhere on the body but usually occurs at the location of the shingles rash. Depression is not uncommon due to the pain and social isolation during the illness.

15

Postherpetic neuralgia may be debilitating long after signs of the original herpes infection have disappeared. Other infectious diseases that may cause neuralgia are syphilis and Lyme disease.

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Diabetes is another common cause of neuralgia. This very common medical problem affects almost 1 out of every 20 Americans during adulthood. Diabetes damages the tiny arteries that supply circulation to the nerves, resulting in nerve fiber malfunction and sometimes nerve loss. Diabetes can produce almost any neuralgia, including trigeminal neuralgia, carpal tunnel syndrome (pain and numbness of the hand and wrist), and meralgia paresthetica (numbness and pain in the thigh due to damage to the lateral femoral cutaneous nerve). Strict control of blood sugar may prevent diabetic nerve damage and may accelerate recovery in patients who do develop neuralgia.

25

Other medical conditions that may be associated with neuralgias are chronic renal insufficiency and porphyria – a hereditary disease in which the body cannot rid itself

30

of certain substances produced after the normal breakdown of blood in the body. Certain drugs may also cause this problem.

2. Deafferentation.

5 Deafferentation indicates a loss of the sensory input from a portion of the body, and can be caused by interruption of either peripheral sensory fibres or nerves from the central nervous system. A deafferentation pain syndrome, includes, without limitation, an injury to the brain or spinal cord, a post-stroke pain, a phantom pain, a paraplegia, a brachial plexus avulsion injuries, lumbar radiculopathies.

10

3. Complex regional pain syndromes (CRPSs)

CRPS is a chronic pain syndrome resulting from sympathetically-maintained pain, and presents in two forms. CRPS 1 currently replaces the term "reflex sympathetic dystrophy syndrome". It is a chronic nerve disorder that occurs most often in the
15 arms or legs after a minor or major injury. CRPS 1 is associated with severe pain; changes in the nails, bone, and skin; and an increased sensitivity to touch in the affected limb. CRPS 2 replaces the term causalgia, and results from an identified injury to the nerve. A CRPS, includes, without limitation, a CRPS Type I (reflex sympathetic dystrophy) and a CRPS Type II (causalgia).

20

4. Neuropathy.

A neuropathy is a functional or pathological change in a nerve and is characterized clinically by sensory or motor neuron abnormalities.

25 Central neuropathy is a functional or pathological change in the central nervous system.

Peripheral neuropathy is a functional or pathological change in one or more peripheral nerves. The peripheral nerves relay information from your central
30 nervous system (brain and spinal cord) to muscles and other organs and from your skin, joints, and other organs back to your brain. Peripheral neuropathy occurs when these nerves fail to carry information to and from the brain and spinal cord, resulting

in pain, loss of sensation, or inability to control muscles. In some cases, the failure of nerves that control blood vessels, intestines, and other organs results in abnormal blood pressure, digestion problems, and loss of other basic body processes. Risk factors for neuropathy include diabetes, heavy alcohol use, and exposure to certain chemicals and drugs. Some people have a hereditary predisposition for neuropathy. Prolonged pressure on a nerve is another risk for developing a nerve injury. Pressure injury may be caused by prolonged immobility (such as a long surgical procedure or lengthy illness) or compression of a nerve by casts, splints, braces, crutches, or other devices. Polyneuropathy implies a widespread process that usually affects both sides of the body equally. The symptoms depend on which type of nerve is affected. The three main types of nerves are sensory, motor, and autonomic. Neuropathy can affect any one or a combination of all three types of nerves. Symptoms also depend on whether the condition affects the whole body or just one nerve (as from an injury). The cause of chronic inflammatory polyneuropathy is an abnormal immune response. The specific antigens, immune processes, and triggering factors are variable and in many cases are unknown. It may occur in association with other conditions such as HIV, inflammatory bowel disease, lupus erythematosus, chronic active hepatitis, and blood cell abnormalities.

Peripheral neuropathy may involve a function or pathological change to a single nerve or nerve group (mononeuropathy) or a function or pathological change affecting multiple nerves (polyneuropathy).

Peripheral neuropathies

Hereditary disorders

Charcot-Marie-Tooth disease

Friedreich's ataxia

Systemic or metabolic disorders

Diabetes (diabetic neuropathy)

Dietary deficiencies (especially vitamin B-12)

Excessive alcohol use (alcoholic neuropathy)

Uremia (from kidney failure)

Cancer

Infectious or inflammatory conditions

AIDS

Hepatitis

5 Colorado tick fever

diphtheria

Guillain-Barre syndrome

HIV infection without development of AIDS

leprosy

10 Lyme

polyarteritis nodosa

rheumatoid arthritis

sarcoidosis

Sjogren syndrome

15 syphilis

systemic lupus erythematosus

amyloid

Exposure to toxic compounds

sniffing glue or other toxic compounds

20 nitrous oxide

industrial agents -- especially solvents

heavy metals (lead, arsenic, mercury, etc.)

Neuropathy secondary to drugs like analgesic nephropathy

Miscellaneous causes

25 ischemia (decreased oxygen/decreased blood flow)

prolonged exposure to cold temperature

a. Polyneuropathy

Polyneuropathy is a peripheral neuropathy involving the loss of movement or sensation to an area caused by damage or destruction to multiple peripheral nerves.

30 Polyneuropathic pain, includes, without limitation, post-polio syndrome, postmastectomy syndrome, diabetic neuropathy, alcohol neuropathy, amyloid, toxins, AIDS, hypothyroidism, uremia, vitamin deficiencies, chemotherapy-induced

pain, 2',3'-didexoycytidine (ddC) treatment, Guillain-Barré syndrome or Fabry's disease.

b. Mononeuropathy

Mononeuropathy is a peripheral neuropathy involving loss of movement or sensation to an area caused by damage or destruction to a single peripheral nerve or nerve group. Mononeuropathy is most often caused by damage to a local area resulting from injury or trauma, although occasionally systemic disorders may cause isolated nerve damage (as with mononeuritis multiplex). The usual causes are direct trauma, prolonged pressure on the nerve, and compression of the nerve by swelling or injury to nearby body structures. The damage includes destruction of the myelin sheath (covering) of the nerve or of part of the nerve cell (the axon). This damage slows or prevents conduction of impulses through the nerve. Mononeuropathy may involve any part of the body. Mononeuropathic pain, includes, without limitation, a sciatic nerve dysfunction, a common peroneal nerve dysfunction, a radial nerve dysfunction, an ulnar nerve dysfunction, a cranial mononeuropathy VI, a cranial mononeuropathy VII, a cranial mononeuropathy III (compression type), a cranial mononeuropathy III (diabetic type), an axillary nerve dysfunction, a carpal tunnel syndrome, a femoral nerve dysfunction, a tibial nerve dysfunction, a Bell's palsy, a thoracic outlet syndrome, a carpal tunnel syndrome and a sixth (abducent) nerve palsy

c. Generalized peripheral neuropathies

Generalized peripheral neuropathies are symmetrical, and usually due to various systematic illnesses and disease processes that affect the peripheral nervous system in its entirety. They are further subdivided into several categories:

i. Distal axonopathies are the result of some metabolic or toxic derangement of neurons. They may be caused by metabolic diseases such as diabetes, renal failure, deficiency syndromes such as malnutrition and alcoholism, or the effects of toxins or drugs. Distal axonopathy (aka dying back neuropathy) is a type of peripheral neuropathy that results from some metabolic or toxic derangement of peripheral nervous system (PNS) neurons. It is the most common response of nerves to metabolic or toxic disturbances, and as such may be caused by metabolic diseases such as diabetes, renal failure, deficiency syndromes such as malnutrition

and alcoholism, or the effects of toxins or drugs. The most common cause of distal axonopathy is diabetes, and the most common distal axonopathy is diabetic neuropathy.

ii. Myelinopathies are due to a primary attack on myelin causing an acute failure of impulse conduction. The most common cause is acute inflammatory demyelinating polyneuropathy (AIDP; aka Guillain-Barré syndrome), though other causes include chronic inflammatory demyelinating syndrome (CIDP), genetic metabolic disorders (e.g., leukodystrophy), or toxins. Myelinopathy is due to primary destruction of myelin or the myelinating Schwann cells, which leaves the axon intact, but causes an acute failure of impulse conduction. This demyelination slows down or completely blocks the conduction of electrical impulses through the nerve. The most common cause is acute inflammatory demyelinating polyneuropathy (AIDP, better known as Guillain-Barré syndrome), though other causes include chronic inflammatory demyelinating polyneuropathy (CIDP), genetic metabolic disorders (e.g., leukodystrophy or Charcot-Marie-Tooth disease), or toxins.

iii. Neuronopathies are the result of destruction of peripheral nervous system (PNS) neurons. They may be caused by motor neurone diseases, sensory neuronopathies (e.g., Herpes zoster), toxins or autonomic dysfunction. Neurotoxins may cause neuronopathies, such as the chemotherapy agent vincristine. Neuronopathy is dysfunction due to damage to neurons of the peripheral nervous system (PNS), resulting in a peripheral neuropathy. It may be caused by motor neurone diseases, sensory neuronopathies (e.g., Herpes zoster), toxic substances or autonomic dysfunction. A person with neuronopathy may present in different ways, depending on the cause, the way it affects the nerve cells, and the type of nerve cell that is most affected.

iv. Focal entrapment neuropathies (e.g., carpal tunnel syndrome).

II. Inflammatory pain

The compounds of the invention may be used to treat pain caused by or otherwise associated with any of the following inflammatory conditions.

A. Arthritic disorder

Arthritic disorders include, for example, a rheumatoid arthritis; a juvenile rheumatoid arthritis; a systemic lupus erythematosus (SLE); a gouty arthritis; a scleroderma; an osteoarthritis; a psoriatic arthritis; an ankylosing spondylitis; a Reiter's syndrome (reactive arthritis); an adult Still's disease; an arthritis from a viral infection; an
5 arthritis from a bacterial infection, such as, e.g., a gonococcal arthritis and a non-gonococcal bacterial arthritis (septic arthritis); a Tertiary Lyme disease; a tuberculous arthritis; and an arthritis from a fungal infection, such as, e.g., a blastomycosis

10 B. Autoimmune diseases

Autoimmune diseases include, for example, a Guillain-Barré syndrome, a Hashimoto's thyroiditis, a pernicious anemia, an Addison's disease, a type I diabetes, a systemic lupus erythematosus, a dermatomyositis, a Sjogren's syndrome, a lupus erythematosus, a multiple sclerosis, a myasthenia gravis, a
15 Reiter's syndrome and a Grave's disease.

C. Connective tissue disorder

Connective tissue disorders include, for example, a spondyloarthritis a dermatomyositis, and a fibromyalgia.

20

D. Injury

Inflammation caused by injury, including, for example, a crush, puncture, stretch of a tissue or joint, may cause chronic inflammatory pain.

25 E. Infection

Inflammation caused by infection, including, for example, a tuberculosis or an interstitial keratitis may cause chronic inflammatory pain.

F. Neuritis

30 Neuritis is an inflammatory process affecting a nerve or group of nerves. Symptoms depend on the nerves involved, but may include pain, paresthesias, paresis, or hypesthesia (numbness).

Examples include:

a. Brachial neuritis

b. Retrobulbar neuropathy, an inflammatory process affecting the part of the optic nerve lying immediately behind the eyeball.

5 c. Optic neuropathy, an inflammatory process affecting the optic nerve causing sudden, reduced vision in the affected eye. The cause of optic neuritis is unknown. The sudden inflammation of the optic nerve (the nerve connecting the eye and the brain) leads to swelling and destruction of the myelin sheath. The inflammation may occasionally be the result of a viral infection, or it may be caused
10 by autoimmune diseases such as multiple sclerosis. Risk factors are related to the possible causes.

d. Vestibular neuritis, a viral infection causing an inflammatory process affecting the vestibular nerve.

15 G. Joint inflammation

Inflammation of the joint, such as that caused by bursitis or tendonitis, for example, may cause chronic inflammatory pain.

III. Headache Pain

20 The compounds of the invention may be used to treat pain caused by or otherwise associated with any of the following headache conditions. A headache (medically known as cephalgia) is a condition of mild to severe pain in the head; sometimes neck or upper back pain may also be interpreted as a headache. It may indicate an underlying local or systemic disease or be a disorder in itself.

25

A. Muscular/myogenic headache

Muscular/myogenic headaches appear to involve the tightening or tensing of facial and neck muscles; they may radiate to the forehead. Tension headache is the most common form of myogenic headache.

30

A tension headache is a condition involving pain or discomfort in the head, scalp, or

neck, usually associated with muscle tightness in these areas. Tension headaches

result from the contraction of neck and scalp muscles. One cause of this muscle contraction is a response to stress, depression or anxiety. Any activity that causes the head to be held in one position for a long time without moving can cause a headache. Such activities include typing or use of computers, fine work with the hands, and use of a microscope. Sleeping in a cold room or sleeping with the neck in an abnormal position may also trigger this type of headache. A tension-type headache, includes, without limitation, an episodic tension headache and a chronic tension headache.

10 B. Vascular headache

The most common type of vascular headache is migraine. Other kinds of vascular headaches include cluster headaches, which cause repeated episodes of intense pain, and headaches resulting from high blood pressure

1. Migraine

15 A migraine is a heterogeneous disorder that generally involves recurring headaches. Migraines are different from other headaches because they occur with other symptoms, such as, e.g., nausea, vomiting, or sensitivity to light. In most people, a throbbing pain is felt only on one side of the head. Clinical features such as type of aura symptoms, presence of prodromes, or associated symptoms such as
20 vertigo, may be seen in subgroups of patients with different underlying pathophysiological and genetic mechanisms. A migraine headache, includes, without limitation, a migraine without aura (common migraine), a migraine with aura (classic migraine), a menstrual migraine, a migraine equivalent (acephalic headache), a complicated migraine, an abdominal migraine and a mixed tension
25 migraine.

2. Cluster headache

Cluster headaches affect one side of the head (unilateral) and may be associated with tearing of the eyes and nasal congestion. They occurs in clusters, happening repeatedly every day at the same time for several weeks and then
30 remitting.

D. High blood pressure headache

E. Traction and inflammatory headache

Traction and inflammatory headaches are usually symptoms of other disorders,
5 ranging from stroke to sinus infection.

F. Hormone headache

G. Rebound headache

10 Rebound headaches, also known as medication overuse headaches, occur when medication is taken too frequently to relieve headache. Rebound headaches frequently occur daily and can be very painful.

H. Chronic sinusitis headache

15 Sinusitis is inflammation, either bacterial, fungal, viral, allergic or autoimmune, of the paranasal sinuses. Chronic sinusitis is one of the most common complications of the common cold. Symptoms include: Nasal congestion; facial pain; headache; fever; general malaise; thick green or yellow discharge; feeling of facial 'fullness' worsening on bending over. In a small number of cases, chronic maxillary sinusitis
20 can also be brought on by the spreading of bacteria from a dental infection. Chronic hyperplastic eosinophilic sinusitis is a noninfective form of chronic sinusitis.

I. An organic headache

25 J. Ictal headaches

Ictal headaches are headaches associated with seizure activity.

IV. Somatic pain

The compounds of the invention may be used to treat pain caused by or otherwise
30 associated with any of the following somatic pain conditions. Somatic pain originates from ligaments, tendons, bones, blood vessels, and even nerves themselves. It is detected with somatic nociceptors. The scarcity of pain receptors in these areas

produces a dull, poorly-localized pain of longer duration than cutaneous pain; examples include sprains and broken bones. Additional examples include the following.

A. Excessive muscle tension

5 Excessive muscle tension can be caused, for example, by a sprain or a strain.

B. Repetitive motion disorders

Repetitive motion disorders can result from overuse of the hands, wrists, elbows, shoulders, neck, back, hips, knees, feet, legs, or ankles.

10

C. Muscle disorders

Muscle disorders causing somatic pain include, for example, a polymyositis, a dermatomyositis, a lupus, a fibromyalgia, a polymyalgia rheumatica, and a rhabdomyolysis.

15

D. Myalgia

Myalgia is muscle pain and is a symptom of many diseases and disorders. The most common cause for myalgia is either overuse or over-stretching of a muscle or group of muscles. Myalgia without a traumatic history is often due to viral infections.

20

Longer-term myalgias may be indicative of a metabolic myopathy, some nutritional deficiencies or chronic fatigue syndrome.

E. Infection

Infection can cause somatic pain. Examples of such infection include, for example,
25 an abscess in the muscle, a trichinosis, an influenza, a Lyme disease, a malaria, a Rocky Mountain spotted fever, Avian influenza, the common cold, community-acquired pneumonia, meningitis, monkeypox, Severe Acute Respiratory Syndrome, toxic shock syndrome, trichinosis, typhoid fever, and upper respiratory tract infection.

30

F. Drugs

Drugs can cause somatic pain. Such drugs include, for example, cocaine, a statin for lowering cholesterol (such as atorvastatin, simvastatin, and lovastatin), and an

ACE inhibitor for lowering blood pressure (such as enalapril and captopril)

V. Visceral pain

The compounds of the invention may be used to treat pain caused by or otherwise
5 associated with any of the following visceral pain conditions. Visceral pain originates
from body's viscera, or organs. Visceral nociceptors are located within body organs
and internal cavities. The even greater scarcity of nociceptors in these areas
produces pain that is usually more aching and of a longer duration than somatic
pain. Visceral pain is extremely difficult to localise, and several injuries to visceral
10 tissue exhibit "referred" pain, where the sensation is localised to an area completely
unrelated to the site of injury. Examples of visceral pain include the following.

A. Functional visceral pain

Functional visceral pain includes, for example, an irritable bowel syndrome and a
15 chronic functional abdominal pain (CFAP), a functional constipation and a functional
dyspepsia, a non-cardiac chest pain (NCCP) and a chronic abdominal pain.

B. Chronic gastrointestinal inflammation

Chronic gastrointestinal inflammation includes, for example, a gastritis, an
20 inflammatory bowel disease, like, e.g., a Crohn's disease, an ulcerative colitis, a
microscopic colitis, a diverticulitis and a gastroenteritis; an interstitial cystitis; an
intestinal ischemia; a cholecystitis; an appendicitis; a gastroesophageal reflux; an
ulcer, a nephrolithiasis, an urinary tract infection, a pancreatitis and a hernia.

25 C. Autoimmune pain

Autoimmune pain includes, for example, a sarcoidosis and a vasculitis.

D. Organic visceral pain

Organic visceral pain includes, for example, pain resulting from a traumatic,
30 inflammatory or degenerative lesion of the gut or produced by a tumor impinging on
sensory innervation.

E. Treatment-induced visceral pain

Treatment-induced visceral pain includes, for example, a pain attendant to chemotherapy therapy or a pain attendant to radiation therapy.

5 VI. Referred pain

The compounds of the invention may be used to treat pain caused by or otherwise associated with any of the following referred pain conditions.

Referred pain arises from pain localized to an area separate from the site of pain
10 stimulation. Often, referred pain arises when a nerve is compressed or damaged at or near its origin. In this circumstance, the sensation of pain will generally be felt in the territory that the nerve serves, even though the damage originates elsewhere. A common example occurs in intervertebral disc herniation, in which a nerve root arising from the spinal cord is compressed by adjacent disc material. Although pain
15 may arise from the damaged disc itself, pain will also be felt in the region served by the compressed nerve (for example, the thigh, knee, or foot). Relieving the pressure on the nerve root may ameliorate the referred pain, provided that permanent nerve damage has not occurred. Myocardial ischaemia (the loss of blood flow to a part of the heart muscle tissue) is possibly the best known example of referred pain; the
20 sensation can occur in the upper chest as a restricted feeling, or as an ache in the left shoulder, arm or even hand.

Conventionally, an agonist has been considered any molecule that can either
25 increase or decrease activities within a cell, namely any molecule that simply causes an alteration of cell activity. For example, the conventional meaning of an agonist would include: a chemical substance capable of combining with a receptor on a cell and initiating a reaction or activity, or a drug that induces an active response by activating receptors, whether the response is an increase or decrease in cellular
30 activity.

However, for the purposes of this invention, an agonist is more specifically defined

as a molecule that is capable of stimulating the process of exocytic fusion in a pain-sensing target cell, which process is susceptible to inhibition by a protease (or fragment thereof) capable of cleaving a protein of the exocytic fusion apparatus in said target cell.

5

Accordingly, the particular agonist definition of the present invention would exclude many molecules that would be conventionally considered as agonists. For example, nerve growth factor (NGF) is an agonist in respect of its ability to promote neuronal differentiation via binding to a TrkA receptor. However, NGF is not an agonist when
10 assessed by the above criteria because it is not a principal inducer of exocytic fusion. In addition, the process that NGF stimulates (i.e. cell differentiation) is not susceptible to inhibition by the protease activity of a non-cytotoxic toxin molecule.

In use, an agonist-containing conjugate of the present invention does not deactivate
15 an agonist receptor on a pain-sensing target cell, but rather the protease activity of the conjugate serves to negate the agonist-mediated response.

Furthermore, once delivered to the cytosol of the pain-sensing target cell, the protease component of a conjugate of the present invention inhibits or blocks the
20 action of all subsequent agonists capable of causing the same effect (i.e. increased exocytic fusion) in the same target cell. This is advantageous and means that the conjugates of the present invention have application in situations where multiple agonists may be responsible for causing the sensation of pain. Thus, when designing a conjugate of the present invention, the TM that is selected for delivery
25 need not necessarily be the principal agonist involved in causing the sensation of pain.

Agonist-mediated delivery according to the present invention provides the following significant advantage over previous non-cytotoxic protease-containing therapeutics:
30 use of an agonist may confer preferential binding and/or internalisation properties on the conjugate. This, in turn, may result in more efficient delivery of the protease component to a pain-sensing target cell.

In addition, use of an agonist as a TM is self-limiting with respect to side-effects. In more detail, binding of an agonist to a pain-sensing target cell increases exocytic fusion, which may exacerbate the sensation of pain. However, the exocytic process that is stimulated by agonist binding is subsequently reduced or inhibited by the protease component of the conjugate.

In preferred embodiments of the invention, the TM is an agonist of the ORL₁ receptor. The ORL₁ receptor is present on pain-sensing cells in the body.

The ORL₁ receptor is a member of the G-protein-coupled class of receptors, and has a seven transmembrane domain structure. The properties of the ORL₁ receptor are discussed in detail in Mogil & Pasternak (2001), *Pharmacological Reviews*, Vol. 53, No. 3, pages 381-415.

Throughout this specification, reference to the "ORL₁ receptor" embraces all members of the ORL₁ receptor family. Members of the ORL₁ receptor family typically have a seven transmembrane domain structure, and are coupled to G-proteins of the G_i and G_o families. A method for determining the G-protein-stimulating activity of ligands of the ORL₁ receptor is given in Example 17. A method for measuring reduction in cellular cAMP levels following ORL₁ activation is given in Example 16. A further characteristic of members of the ORL₁ receptor family is that they are typically able to bind nociceptin (the natural ligand of ORL₁). As an example, all alternative splice variants of the ORL₁ receptor, are members of the ORL₁ receptor family.

The conjugates of the present invention generally demonstrate a reduced binding affinity (in the region of up to 100-fold) for nociceptive sensory afferent target cells when compared with the corresponding 'free' TM. However, despite this observation, the conjugates of the present invention surprisingly demonstrate good efficacy. This can be attributed to two principal features. First, the non-cytotoxic protease component is catalytic – thus; the therapeutic effect of a few such

molecules is rapidly amplified. Secondly, the receptors present on the nociceptive sensory afferents need only act as a gateway for entry of the therapeutic, and need not necessarily be stimulated to a level required in order to achieve a ligand-receptor mediated pharmacological response. Accordingly, the conjugates of the present invention may be administered at a dosage that is much lower that would be employed for other types of analgesic molecules such as NSAIDS, morphine, and gabapentin. The latter molecules are typically administered at high microgram to milligram (even up to hundreds of milligram) quantities, whereas the conjugates of the present invention may be administered at much lower dosages, typically at least 10-fold lower, and more typically at 100-fold lower.

In a particularly preferred embodiment of the invention, the TM of the conjugate is nociceptin - the natural ligand for the ORL₁ receptor. Nociceptin targets the ORL₁ receptor with high affinity.

Examples of other preferred TMs include:

Code	Sequence	Ref.	SEQ ID No.
Nociceptin 1-17	FGGFTGARKSARKLANQ	[1]	1,2
Nociceptin 1-11	FGGFTGARKSA	[1]	3,4
Nociceptin [Y10]1-11	FGGFTGARKYA	[1]	5,6
Nociceptin [Y11]1-11	FGGFTGARKSY	[1]	7,8
Nociceptin [Y14]1-17	FGGFTGARKSARKYANQ	[1]	9,10
Nociceptin 1-13	FGGFTGARKSARK	[2]	11,12
Nociceptin [R14K15]	FGGFTGARKSARKRKNQ	[3,4]	13,14

Code	Sequence	Ref.	SEQ ID No.
1-17 (also known as "variant" nociceptin)			
Nociceptin 1-13-NH ₂	FGGFTGARKSARK-NH ₂	[5]	-
Nociceptin Phe (<i>p</i> -NO ₂) 1-17	(<i>p</i> NO ₂)FGGFTGARKSARKLANQ	[5]	-
Lofentanil	Non-peptide agonists	[5]	-
Etorphine	Non-peptide agonists	[5]	-
Peptide agonist	Peptide agonists from combinatorial library approach	[6]	-

[1] Mogil & Pasternak, 2001, Pharmacol. Rev., 53, 381-415

[2] Maile et al., 2003, Neurosci. Lett., 350, 190-192

[3] Rizzi et al., 2002, J. Pharmacol. Exp. Therap., 300, 57-63

5 [4] Okada et al., 2000, Biochem. Biophys. Res. Commun., 278, 493-498

[5] Zaveri, 2003, Life Sci., 73, 663-678.

[6] Dooley et al., 1997, J Pharmacol Exp Ther. 283(2), 735-41.

10 The TM preferably comprises a maximum of 50 amino acid residues, more preferably a maximum of 40 amino acid residues, particularly preferably a maximum of 30 amino acid residues, and most preferably a maximum of 20 amino acid residues. For example, nociceptin is a 17 amino acid residue peptide.

15 The above-identified "variant" TM demonstrates particularly good binding affinity (when compared with natural nociceptin) for nociceptive sensory afferents. Generally speaking, a TM-containing conjugate will demonstrate an approximate 100-fold reduction in binding ability *vis-à-vis* the TM *per se*. The above-mentioned "variant" TM *per se* demonstrates an approximate 3- to 10-fold increase in binding ability for a nociceptive sensory afferent *vis-à-vis* natural nociceptin. Thus, a "variant" TM-
20 containing fusion might be expected to demonstrate an approximate 10-fold reduction in binding ability for a nociceptive sensory afferent *vis-à-vis* 'free'

nociceptin. However, the present inventors have demonstrated that conjugates comprising said "variant" TM demonstrate a binding ability that (most surprisingly) closely mirrors that of 'free' nociceptin – see Figure 17.

5 In the context of the present invention, the term agonist of the ORL₁ receptor (such as nociceptin, or any one of the peptides listed in the table above) embraces molecules having at least 70%, preferably at least 80%, more preferably at least 90%, and most preferably at least 95% homology with said agonist. The agonist homologues retain the agonist properties of nociceptin at the ORL₁ receptor, which
10 may be tested using the methods provided in Example 10.

The invention also encompasses fragments, variants, and derivatives of any one of the TMs described above. These fragments, variants, and derivatives will substantially retain the properties that are ascribed to said TMs.

15

The agonist properties of a TM can be confirmed using the methods described in Example 1. These methods are based on previous experiments (see Inoue *et al.* (1998) Proc. Natl. Acad. Sci., 95, 10949-10953), which confirm that the natural agonist of the ORL₁ receptor, nociceptin, causes the induction of substance P
20 release from nociceptive primary afferent neurons. This is supported by the facts that:

- the nociceptin-induced responses are abolished by specific NK1 receptor (the substance P receptor) antagonists; and

25

- pre-treatment of the cells with capsaicin (which depletes substance P from small diameter primary afferent neurons) attenuates the nociceptin-induced responses.

30 Similarly, Inoue *et al.* confirm that an intraplantar injection of botulinum neurotoxin type A abolishes the nociceptin-induced responses. Since it is known that BoNT inhibits the release of substance P from primary afferent neurons (Welch *et al.*,

(2000), Toxicon, 38, 245-258), this confirms the link between nociceptin-ORL₁ interaction and subsequent release of substance P.

Thus, a TM can be said to have agonist activity at the ORL₁ receptor if the TM
5 causes an induction in the release of substance P from a nociceptive sensory afferent neuron (see Example 1).

In another embodiment, opioids represent a preferred group of TMs of the present invention. Within this family of peptides is included enkephalins (met and leu),
10 endomorphins 1 and 2, β -endorphin and dynorphin. Opioid peptides are frequently used in the clinic to modify the activity to nociceptors, and other cells involved in the pain response. As exemplified by the three-step World Health Organisation Analgesic Ladder, opioids have entry points into the pharmacological treatment of chronic cancer and non-cancer pain at all three stages, underlining their importance
15 to the treatment of pain. Reference to opioids embraces fragments, variants and derivatives thereof, which retain the ability to bind to nociceptive sensory afferents. The protease of the present invention embraces all naturally-occurring non-cytotoxic proteases that are capable of cleaving one or more proteins of the exocytic fusion apparatus in eukaryotic cells.

20

The protease of the present invention is preferably a bacterial protease.

More preferably, the bacterial protease is selected from the genera *Clostridium* or *Neisseria* (e.g. a clostridial L-chain, or a neisserial IgA protease preferably from *N. gonorrhoeae*).
25

The present invention also embraces modified non-cytotoxic proteases, which include amino acid sequences that do not occur in nature and/or synthetic amino acid residues, so long as the modified proteases still demonstrate the above-
30 mentioned protease activity.

~~The protease of the present invention preferably demonstrates a serine or~~

metalloprotease activity (e.g. endopeptidase activity). The protease is preferably specific for a SNARE protein (e.g. SNAP-25, synaptobrevin/VAMP, or syntaxin).

Particular mention is made to the protease domains of neurotoxins, for example the protease domains of bacterial neurotoxins. Thus, the present invention embraces the use of neurotoxin domains, which occur in nature, as well as recombinantly prepared versions of said naturally-occurring neurotoxins.

Exemplary neurotoxins are produced by clostridia, and the term clostridial neurotoxin embraces neurotoxins produced by *C. tetani* (TeNT), and by *C. botulinum* (BoNT) serotypes A-G, as well as the closely related BoNT-like neurotoxins produced by *C. baratii* and *C. butyricum*. The above-mentioned abbreviations are used throughout the present specification. For example, the nomenclature BoNT/A denotes the source of neurotoxin as BoNT (serotype A). Corresponding nomenclature applies to other BoNT serotypes.

The term L-chain fragment means a component of the L-chain of a neurotoxin, which fragment demonstrates a metalloprotease activity and is capable of proteolytically cleaving a vesicle and/or plasma membrane associated protein involved in cellular exocytosis.

A Translocation Domain is a molecule that enables translocation of a protease (or fragment thereof) into a pain-sensing target cell such that a functional expression of protease activity occurs within the cytosol of the target cell. Whether any molecule (e.g. a protein or peptide) possesses the requisite translocation function of the present invention may be confirmed by any one of a number of conventional assays.

For example, Shone C. (1987) describes an *in vitro* assay employing liposomes, which are challenged with a test molecule. Presence of the requisite translocation function is confirmed by release from the liposomes of K^+ and/or labelled NAD, which may be readily monitored (see Shone C. (1987) Eur. J. Biochem; vol. 167(1): pp.175-180).

A further example is provided by Blaustein R. (1987), which describes a simple *in vitro* assay employing planar phospholipid bilayer membranes. The membranes are challenged with a test molecule and the requisite translocation function is confirmed
5 by an increase in conductance across said membranes (see Blaustein (1987) FEBS Letts; vol. 226, no. 1: pp. 115-120).

Additional methodology to enable assessment of membrane fusion and thus identification of Translocation Domains suitable for use in the present invention are
10 provided by *Methods in Enzymology*, Vols. 220 and 221, Membrane Fusion Techniques, Parts A and B, Academic Press 1993.

The Translocation Domain is preferably capable of formation of ion-permeable pores in lipid membranes under conditions of low pH. Preferably, it has been found to use
15 only those portions of the protein molecule capable of pore-formation within the endosomal membrane.

The Translocation Domain may be obtained from a microbial protein source, in particular from a bacterial or viral protein source. Hence, in one embodiment, the
20 Translocation Domain is a translocating domain of an enzyme, such as a bacterial toxin or viral protein.

It is well documented that certain domains of bacterial toxin molecules are capable of forming such pores. It is also known that certain translocation domains of virally
25 expressed membrane fusion proteins are capable of forming such pores. Such domains may be employed in the present invention.

The Translocation Domain may be of a clostridial origin, namely the H_N domain (or a functional component thereof). H_N means a portion or fragment of the H-chain of a
30 clostridial neurotoxin approximately equivalent to the amino-terminal half of the H-chain, or the domain corresponding to that fragment in the intact H-chain. Examples of suitable clostridial Translocation Domains include:

	Botulinum type A neurotoxin	-	amino acid residues (449-871)
	Botulinum type B neurotoxin	-	amino acid residues (441-858)
	Botulinum type C neurotoxin	-	amino acid residues (442-866)
5	Botulinum type D neurotoxin	-	amino acid residues (446-862)
	Botulinum type E neurotoxin	-	amino acid residues (423-845)
	Botulinum type F neurotoxin	-	amino acid residues (440-864)
	Botulinum type G neurotoxin	-	amino acid residues (442-863)
	Tetanus neurotoxin	-	amino acid residues (458-879)

10

For further details on the genetic basis of toxin production in *Clostridium botulinum* and *C. tetani*, we refer to Henderson *et al.* (1997) in *The Clostridia: Molecular Biology and Pathogenesis*, Academic press.

15 The term H_N embraces naturally-occurring neurotoxin H_N portions, and modified H_N portions having amino acid sequences that do not occur in nature and/or synthetic amino acid residues, so long as the modified H_N portions still demonstrate the above-mentioned translocation function.

20 Alternatively, the Translocation Domain may be of a non-clostridial origin (see table below). Examples of non-clostridial Translocation Domain origins include, but are not restricted to, the translocation domain of diphtheria toxin [O'Keefe *et al.*, Proc. Natl. Acad. Sci. USA (1992) 89, 6202-6206; Silverman *et al.*, J. Biol. Chem. (1993) 269, 22524-22532; and London, E. (1992) *Biochem. Biophys. Acta.*, 1112, pp.25-51], the translocation domain of *Pseudomonas* exotoxin type A [Prior *et al.* Biochemistry (1992) 31, 3555-3559], the translocation domains of anthrax toxin [Blanke *et al.* Proc. Natl. Acad. Sci. USA (1996) 93, 8437-8442], a variety of fusogenic or hydrophobic peptides of translocating function [Plank *et al.* J. Biol. Chem. (1994) 269, 12918-12924; and Wagner *et al* (1992) *PNAS*, 89, pp.7934-7938], and amphiphilic peptides [Murata *et al* (1992) *Biochem.*, 31, pp.1986-1992].

30

The Translocation Domain may mirror the Translocation Domain present in a naturally-occurring protein, or may include amino acid variations so long as the

variations do not destroy the translocating ability of the Translocation Domain.

Particular examples of viral Translocation Domains suitable for use in the present invention include certain translocating domains of virally expressed membrane fusion proteins. For example, Wagner *et al.* (1992) and Murata *et al.* (1992) describe the translocation (i.e. membrane fusion and vesiculation) function of a number of fusogenic and amphiphilic peptides derived from the N-terminal region of influenza virus haemagglutinin. Other virally expressed membrane fusion proteins known to have the desired translocating activity are a translocating domain of a fusogenic peptide of Semliki Forest Virus (SFV), a translocating domain of vesicular stomatitis virus (VSV) glycoprotein G, a translocating domain of SER virus F protein and a translocating domain of Foamy virus envelope glycoprotein. Virally encoded "spike proteins" have particular application in the context of the present invention, for example, the E1 protein of SFV and the G protein of VSV.

15

Use of the Translocation Domains (listed below) includes use of sequence variants thereof. A variant may comprise one or more conservative nucleic acid substitutions and/or nucleic acid deletions or insertions, with the proviso that the variant possesses the requisite translocating function. A variant may also comprise one or more amino acid substitutions and/or amino acid deletions or insertions, so long as the variant possesses the requisite translocating function.

20

Translocation Domain source	Amino acid residues	References
Diphtheria toxin	194-380	Silverman <i>et al.</i> , 1994, J. Biol. Chem. 269, 22524-22532 London E., 1992, Biochem. Biophys. Acta., 1113, 25-51
Domain II of pseudomonas exotoxin	405-613	Prior <i>et al.</i> , 1992, Biochemistry 31, 3555-3559 Kihara & Pastan, 1994, Bioconj Chem. 5, 532-538

Translocation Domain source	Amino acid residues	References
Influenza virus haemagglutinin	GLFGAIAGFIENGWE GMIDGWYG, and Variants thereof	Plank <i>et al.</i> , 1994, J. Biol. Chem. 269, 12918-12924 Wagner <i>et al.</i> , 1992, PNAS, 89, 7934-7938 Murata <i>et al.</i> , 1992, Biochemistry 31, 1986-1992
Semliki Forest virus fusogenic protein	Translocation domain	Kielian <i>et al.</i> , 1996, J Cell Biol. 134(4), 863-872
Vesicular Stomatitis virus glycoprotein G	118-139	Yao <i>et al.</i> , 2003, Virology 310(2), 319-332
SER virus F protein	Translocation domain	Seth <i>et al.</i> , 2003, J Virol 77(11) 6520-6527
Foamy virus envelope glycoprotein	Translocation domain	Picard-Maureau <i>et al.</i> , 2003, J Virol. 77(8), 4722-4730

Once a potential receptor agonist (e.g. an ORL1 agonist) has been identified, one or more of the following optional steps may be carried out:

- 5 (A) confirming that the putative agonist molecule or agonist is capable of being combined with a non-cytotoxic protease (or a fragment thereof) and optionally a Translocation Domain to form a conjugate of the present invention; and/or
- 10 (B) confirming that said putative agonist molecule or agonist binds to the receptor on the pain-sensing target cell, which receptor is susceptible to receptor-mediated endocytosis; and/or

(C) confirming that said putative agonist molecule or agonist is able to deliver a non-cytotoxic protease (or fragment thereof) into the cytosol of a pain-sensing target cell.

5 The above steps (A)-(C) may be confirmed by routine tests that would be readily available to a skilled person.

For example, step (A) may be performed by a simple chemical conjugation experiment using conventional conjugation reagents and/or linker molecules, followed by native polyacrylamide gel electrophoresis to confirm that a conjugate of
10 the present invention is formed that has the anticipated molecular weight. The conjugate components are typically linked together (optionally via linker molecules) by covalent bonds.

For example, step (B) may be performed by any one of a range of methodologies for
15 assessment of binding of a ligand. Standard text, for example "Receptor-Ligand Interactions. A Practical Approach. Ed. E. C. Hulme, IRL Press, 1992" are available that describe such approaches in detail. In brief, the agonist or putative agonist molecule is labelled (for example, with 125-iodine) and applied to a cell preparation *in vitro* in the presence of an excess of unlabelled agonist. The purpose of the
20 unlabelled material is to saturate any non-specific binding sites. The agonist is incubated with the cell preparation for sufficient time to achieve equilibrium, and the amount of label bound to the cells assessed by measuring cell associated radioactivity, for example by scintillation or gamma counting.

25 A further example involves gold-labelling of the agonist (or putative agonist), followed by the use of electron microscopy to monitor the cellular transport progress of the labelled agonist [see the basic methodology described by Rabinowitz S. (1992); J. Cell. Biol. 116(1): pp. 95-112; and that described by van Deurs (1986); J. Cell. Biol. 102: pp. 37-47].

30

For example, step (C) may be performed by contacting the conjugate prepared in step (A) with a suitable target cell and assessing cleavage of the substrate. This is

performed by extraction of the SNARE proteins, followed by Western blotting of SDS-PAGE-separated samples. Cleavage of substrate is indicative of delivery of the protease into the target cell. In this regard, cleavage may be monitored by disappearance of substrate and/or appearance of cleavage product. A particularly
5 useful antibody that selectively binds to the cleaved substrate product is described in WO95/33850.

Preparation of a conjugate according to the present invention is now discussed.

10 It is known in the art that the H_C portion of a neurotoxin molecule can be removed from the other portion of the H-chain, known as H_N, such that the H_N fragment remains disulphide linked to the L-chain of the neurotoxin providing a fragment known as LH_N. Thus, in one embodiment of the present invention the LH_N fragment of a neurotoxin is covalently linked, using linkages which may include one or more
15 spacer regions, to a TM.

In another embodiment of the invention, the H_C domain of a neurotoxin is mutated, blocked or modified, e.g. by chemical modification, to reduce or preferably incapacitate its ability to bind the neurotoxin to receptors at the neuromuscular
20 junction. This modified neurotoxin is then covalently linked, using linkages which may include one or more spacer regions, to a TM.

In another embodiment of the invention, the H-chain of a neurotoxin, in which the H_C domain is mutated, blocked or modified, e.g. by chemical modification, to reduce or
25 preferably incapacitate its native binding ability, is combined with the L-chain of a different neurotoxin, or another protease capable of cleaving a protein of the exocytic fusion apparatus (e.g. IgA protease of *N. gonorrhoeae*). This hybrid, modified neurotoxin is then covalently linked, using linkages which may include one or more spacer regions, to a TM.

30

In another embodiment of the invention, the H_N domain of a neurotoxin is combined with the L-chain of a different neurotoxin, or another protease capable of cleaving a

protein of the exocytic fusion apparatus (e.g. IgA protease of *N. gonorrhoeae*). This hybrid is then covalently linked, using linkages which may include one or more spacer regions, to a TM.

5 In another embodiment of the invention, the protease (for example the L-chain component of a neurotoxin) is covalently linked, using linkages that may include one or more spacer regions, to a TM that can also effect the internalisation of the protease into the cytoplasm of the relevant target cell(s).

10 In another embodiment of the invention, the protease (for example the L-chain component of a neurotoxin) is covalently linked, using linkages which may include one or more spacer regions, to a translocation domain to effect transport of the protease fragment into the cytosol.

15 In use, the domains of a conjugate according to the present invention are associated with each other. In one embodiment, two or more of the domains may be joined together either directly (e.g. by a covalent linkage), or via a linker molecule.

A variety of different linker/ spacer molecules may be employed in any of the fusion
20 proteins of the present invention. Examples of such spacer molecules include those illustrated in Figures 31 and 32. Particular mention here is made to GS15, GS20, GS25, and Hx27 – see Figures 31 and 32.

The present inventors have unexpectedly found that non-cytotoxic protease-TM
25 conjugates (eg. CPNv/A) may demonstrate an improved binding activity for nociceptive sensory afferents when the size of the spacer is selected so that (in use) the TM (preferably the C-terminus thereof) and the translocation domain (preferably the N-terminus thereof) are separated from one another by 40-105 angstroms, preferably by 50-100 angstroms, and more preferably by 50-90 angstroms. In
30 another embodiment, the preferred spacers have an amino acid sequence of 11-29 amino acid residues, preferably 15-27 amino acid residues, and more preferably 20-
27 amino acid residues. Suitable spacers may be routinely identified and obtained

according to Crasto, C.J. and Feng, J.A. (2000) May, 13(5), pp. 309-312 – see also
<http://www.fccc.edu/research/labs/feng/limker.html>.

Conjugation techniques suitable for use in the present invention have been well
 5 documented and are routine for a person skilled in the art.

The methodology involved in coupling two protein molecules (A and B) together is
 simple, and is achieved through the use of a cross-linking agent (also known as a
 chemical coupling agent). For example, molecules A and B are separately
 10 contacted with a cross-linking agent, which chemically modifies a specific surface
 group on each of molecules A and B thereby forming derivatised molecules A' and
 B'. The modified surface group on molecule A' is capable of covalently bonding with
 the modified surface group on molecule B'. Thus, the coupling reaction is completed
 by mixing together the two protein molecules A' and B'.

15

Chemical conjugation is illustrated by reference to the following embodiments, where
 P = non-cytotoxic protease component, T = translocation component, and TM =
 targeting moiety.

20 In one embodiment, a single chain P – T is prepared, which is then conjugated to a
 TM. In another embodiment, a single chain TM – T (or T – TM) is prepared, which is
 then conjugated to a P. In a further embodiment, a single chain P – TM (or TM – P)
 is prepared, which is then conjugated to a T. Another particularly preferred
 conjugate has the structure P – TM – T (with an optional protease cleavage site
 25 between P and TM).

30

Where the T and P components are prepared as a single chain polypeptide, a
 protease cleavage site is typically included between said components. Any protease
 cleavage site may be employed in this regard.

In an alternative embodiment, the three components may be simultaneously or
 sequentially conjugated together. Thus, the conjugation may be a one- or two-step

process, and may include one or more different coupling agents.

Chemical coupling agents and cross-linking agents have been commercially available for many years.

5

Example 5 of the present invention describes in detail the use of one such coupling agent, namely SPDP, to chemically couple two protein molecules (nociceptin, and the LH_N of botulinum neurotoxin). The two molecules are separately contacted with SPDP, and then mixed together to allow covalent conjugation.

10

The conjugate described in Example 6 confirms that another coupling agent, PDPH/EDAC, or Traut's reagent, may be employed as an alternative coupling agent to SPDP.

15

SPDP and Traut's reagent are popular and well-documented coupling agents in the technical field of protein conjugation chemistry and are presented here simply as two examples of a well known class of compounds that may be employed to covalently link together the Targeting Moiety component and the clostridial neurotoxin component of the conjugate of the present invention. Other suitable agents include SMPB, SMCC (succinimidyl 4-(N-maleimidomethyl) cyclohexan-1-carboxylate), and LC-SPDP.

20

In more detail, commercially available members of the well-known coupling agents may be used for conjugation purposes to produce a conjugate of the invention.

25

Details of such agents can be found in the following publications:

Hermanson, G.T. (1996), Bioconjugate techniques, Academic Press;

Wong, S.S. (1991), Chemistry of protein conjugation and cross-linking,

30

CRC Press;

Thorpe et al (1987); Cancer Res, 1987, 47, 5924-31. This paper

describes the use of SMBT (sodium S-4-succinimidylloxycarbonyl-alpha-methyl benzyl thiosulfate) and SMPT (4-succinimidylloxycarbonyl-alpha-methyl-alpha(2-pyridyldithio)toluene); and

5

Peeters et al (1989), J Immunol Methods. 1989, 120, 133-43. This paper describes the use of 4 coupling reagents, MHS (succinimidyl 6-(N-maleimido)-n-hexanoate), SMCC (succinimidyl 4-(N-maleimidomethyl)-cyclohexane-1-carboxylate), MBS (succinimidyl m-maleimidobenzoate), and SPDP.

10

The conjugates according to the present invention may also be prepared recombinantly, as detailed in Examples 9 to 12.

15 In one embodiment, the preparation of a recombinant conjugate involves arrangement of the coding sequences of a selected TM, a selected non-cytotoxic protease component, and a translocation component (in any order) in a single genetic construct. These coding sequences may be arranged in-frame so that subsequent transcription and translation is continuous through both coding
20 sequences and results in a fusion protein. All constructs would have a 5' ATG codon to encode an N-terminal methionine, and a C-terminal translational stop codon.

Thus, the recombinant preparation method results in the generation of a single chain polypeptide. In order to activate this polypeptide, a protease cleavage site is present
25 between the non-cytotoxic protease component and the translocation component. Cleavage of this site generates a di-chain polypeptide in which the protease and translocation domains are linked together by way of a covalent bond, preferably a disulphide bond. In this regard, any protease cleavage site may be employed.

30 In the single polypeptide aspect of the present invention, the TM is preferably either N- or C-terminally located with respect to the fusion protein. In other words, it is preferred that the TM is not located between the P and T components of the single

polypeptide fusion protein. In a particularly preferred embodiment, the TM is N-terminally located with respect to the fusion protein.

In one embodiment, an L-chain of a clostridial neurotoxin or another protease
5 capable of cleaving a protein of the exocytic fusion apparatus (e.g. an IgA protease),
or a fragment/variant thereof, may be expressed recombinantly as a fusion protein
with a TM, which TM can also effect the internalisation of the L-chain component
into the cytoplasm of the relevant target cell(s) responsible for secretion.
Alternatively, the fusion protein may further comprise a Translocation Domain. The
10 expressed fusion protein may include one or more spacer regions.

By way of example, the following information is required to produce, recombinantly,
an agent of the present invention:

- 15 (I) DNA sequence data relating to a selected TM;
(II) DNA sequence data relating to the protease component;
(III) DNA sequence data relating to the translocation domain; and
(IV) a protocol to permit construction and expression of the
construct comprising (I), (II) and (III).

20

All of the above basic information (I)-(IV) are either readily available, or are readily
determinable by conventional methods. For example, both WO98/07864 and
WO99/17806 exemplify recombinant technology suitable for use in the present
application.

25

In addition, methods for the construction and expression of the constructs of the
present invention may employ information from the following references and others:

30 Lorberboum-Galski, H., FitzGerald, D., Chaudhary, V., Adhya, S.,
Pastan, I. (1988), Cytotoxic activity of an interleukin 2-Pseudomonas
exotoxin chimeric protein produced in Escherichia coli. Proc.Natl.

Murphy, J.R. (1988), Diphtheria-related peptide hormone gene fusions: a molecular genetic approach to chimeric toxin development. *Cancer Treat. Res.*; 37:123-40;

5

Williams, D.P., Parker, K., Bacha, P., Bishai, W., Borowski, M., Genbauffe, F., Strom, T.B., Murphy, J.R. (1987), Diphtheria toxin receptor binding domain substitution with interleukin-2: genetic construction and properties of a diphtheria toxin-related interleukin-2 fusion protein. *Protein Eng*;1(6):493-8;

10

Arora, N., Williamson, L.C., Leppla, S.H., Halpern, J.L. (1994), Cytotoxic effects of a chimeric protein consisting of tetanus toxin light chain and anthrax toxin lethal factor in non-neuronal cells *J. Biol. Chem.*, 269(42):26165-71;

15

Brinkmann, U., Reiter, Y., Jung, S.H., Lee, B., Pastan, I. (1993), A recombinant immunotoxin containing a disulphide-stabilized Fv fragment. *Proc. Natl. Acad. Sci. USA*, 90(16):7538-42; and

20

O'Hare, M., Brown, A.N., Hussain, K., Gebhardt, A., Watson, G., Roberts, L.M., Vitetta, E.S., Thorpe, P.E., Lord, J.M. (1990), Cytotoxicity of a recombinant ricin-A-chain fusion protein containing a proteolytically-cleavable spacer sequence. *FEBS Lett* Oct 29;273(1-2):200-4.

25

Suitable clostridial neurotoxin sequence information relating to L- and LH_N-chains may be obtained from, for example, Kurazono, H. (1992) *J. Biol. Chem.*, vol. 267, No. 21, pp.14721-14729; and Popoff, M.R., and Marvaud, J.-C. (1999) *The Comprehensive Sourcebook of Bacterial Protein Toxins*, 2nd edition (ed. Alouf, J.E., and Freer, J.H.), Academic Press, pp.174-201.

30

All of the aforementioned publications are hereby incorporated into the present specification by reference thereto.

Similarly, suitable TM sequence data are widely available in the art. Alternatively,
5 any necessary sequence data may be obtained by techniques which are well-known to the skilled person.

For example, DNA encoding the TM component may be cloned from a source organism by screening a cDNA library for the correct coding region (for example by
10 using specific oligonucleotides based on the known sequence information to probe the library), isolating the TM DNA, sequencing this DNA for confirmation purposes, and then placing the isolated DNA in an appropriate expression vector for expression in the chosen host.

15 As an alternative to isolation of the sequence from a library, the available sequence information may be employed to prepare specific primers for use in PCR, whereby the coding sequence is then amplified directly from the source material and, by suitable use of primers, may be cloned directly into an expression vector.

20 Another alternative method for isolation of the coding sequence is to use the existing sequence information and synthesise a copy, possibly incorporating alterations, using DNA synthesis technology. For example, DNA sequence data may be generated from existing protein and/or RNA sequence information. Using DNA synthesis technology to do this (and the alternative described above) enables the
25 codon bias of the coding sequence to be modified to be optimal for the chosen expression host. This may give rise to superior expression levels of the fusion protein.

Optimisation of the codon bias for the expression host may be applied to the DNA
30 sequences encoding the TM and clostridial components of the construct. Optimisation of the codon bias is possible by application of the protein sequence into freely available DNA/protein database software, e.g. programs available from

Genetics Computer Group, Inc.

Having prepared a conjugate of the invention, it is a matter of routine to confirm that the various domains have retained their specified function.

5

Protease function after conjugation may be tested by using, for example, any one of the following routine tests:

10 SNAP-25 (or synaptobrevin, or syntaxin) may be challenged with a conjugate to be tested, and then analysed by SDS-PAGE peptide separation techniques. Subsequent detection of peptides (e.g. by silver staining) having molecular weights corresponding to the cleaved products of SNAP-25 (or other component of the neurosecretory machinery) would confirm the presence of a functional L-chain.

15 As a further alternative, the conjugate may be tested by assaying for SNAP-25 (or synaptobrevin, or syntaxin) cleavage products via antibody-specific binding (see WO95/33850). In more detail, a specific antibody is employed for detecting cleavage of SNAP-25. Since the antibody recognises cleaved SNAP-25, but not uncleaved SNAP-25, identification of the cleaved product by the antibody confirms
20 the presence of L-chain proteolytic function. By way of exemplification, such a method is described in Examples 2 and 3 of WO96/33273.

Translocation component function after conjugation may be tested using, for example, any one of the following routine tests:

25

Suitable methods are, for example, described by Shone *et al.* (1987) Eur. J. Biochem. 167, pp.175-180; and by Blaustein *et al.* (1987) FEBS 226 (1), pp.115-120.

30 The Shone *et al.* method employs artificial liposomes loaded with potassium phosphate buffer (pH 7.2) and radiolabelled NAD. Release of K⁺ and NAD from the liposomes correlates with a positive result for channel forming activity and hence

translocation activity. In this regard, K⁺ release from liposomes may be measured using an electrode and NAD release calculated by measuring the radioactivity in the supernatant (see page 176, column 1, line 33 - column 2, line 17).

5 The Blaustein *et al.* method employs planar phospholipid bilayer membranes, which are used to test for channel forming activity. In more detail, salt solutions on either side of the membrane are buffered at a different pH - on the cis side, pH 4.7 or 5.5 and on the trans side, pH 7.4. The "conjugate" to be tested is added to the cis side of the membrane and electrical measurements are made under voltage clamp
10 conditions, in order to monitor the flow of current across the membrane (see paragraph 2.2, pages 116-118). The presence of an active translocation function is confirmed by a steady rate of channel turn-on (i.e. a positive result for channel formation) -see paragraph 3, page 118.

15 Targeting Moiety (TM) function after conjugation may be tested by assaying for the agonist function inherent to the TM. Suitable methods include those described in Example 1.

The ability of the conjugate of the invention to inhibit substance P release from
20 nociceptive afferent cells can be assessed using the methods described in Example 15.

In Example 15, a nociceptin-LHN/A conjugate according to the first aspect of the invention is assessed for its ability to inhibit the release of substance P from primary
25 nociceptive sensory afferent neurons. As can be seen from Table 1, incubation of the conjugate with cultures of nociceptive afferent neurons results in a significant inhibition of release of substance P (when compared to incubation of the cells with LHN/A alone). The experiment therefore confirms that the conjugate is inhibiting substance P release from these cells.

30

In use of the present invention, a pain-sensing target cell is selected in which it is

desired to reduce or inhibit the process of exocytic fusion, which exocytic process

contributes to the symptoms associated with the sensation of pain. For example, the target cell in question may demonstrate an undesirable phenotype (e.g. an undesirable secretion, or the expression of an undesirable concentration of membrane receptor, transporter or membrane channel), which contributes to the symptoms associated with pain. Alternatively, a target cell may be selected in which the process of exocytic fusion contributes to the sensation of pain.

In preferred embodiments of the invention, the target cell is a nociceptive sensory afferent cell, preferably a primary nociceptive afferent cell (e.g. an A-fibre such as an A δ -fibre or a C-fibre). Thus, the conjugates of the present invention are capable of inhibiting neurotransmitter or neuromodulator (e.g. glutamate, substance P, calcitonin-gene related peptide (CGRP), and/or neuropeptide Y) release from discrete populations of nociceptive sensory afferent neurons. In use, the conjugates reduce or prevent the transmission of sensory afferent signals (e.g. neurotransmitters or neuromodulators) from peripheral to central pain fibres, and therefore have application as therapeutic molecules for the treatment of pain, in particular chronic pain.

It is routine to confirm that a TM binds to a nociceptive sensory afferent. For example, a simple radioactive displacement experiment may be employed in which tissue or cells representative of the nociceptive sensory afferent (for example DRGs) are exposed to labelled (e.g. tritiated) ligand in the presence of an excess of unlabelled ligand. In such an experiment, the relative proportions of non-specific and specific binding may be assessed, thereby allowing confirmation that the ligand binds to the nociceptive sensory afferent target cell. Optionally, the assay may include one or more binding antagonists, and the assay may further comprise observing a loss of ligand binding. Examples of this type of experiment can be found in Hulme, E.C. (1990), Receptor-binding studies, a brief outline, pp 303-311, in Receptor biochemistry, A Practical Approach, Ed. E.C. Hulme, Oxford University Press.

According to a second aspect, the present invention provides use of a therapeutic

molecule for the manufacture of a medicament for the treatment of a particular type of pain, wherein the therapeutic molecule is a non-cytotoxic conjugate that binds to a nociceptive sensory afferent cell, and comprises:

5 (i) a Targeting Moiety (TM),

wherein said TM is an agonist of a receptor that is present on said nociceptive sensory afferent cell, and wherein said receptor undergoes endocytosis to be incorporated into an endosome within the nociceptive sensory afferent cell;

10

(ii) a DNA sequence encoding a non-cytotoxic protease or a fragment thereof,

wherein the DNA sequence is expressible in the nociceptive sensory afferent cell and when so expressed provides a protease or protease fragment capable of cleaving a protein of the exocytic fusion apparatus of said nociceptive sensory afferent cell; and

15

20

(iii) a Translocation Domain,

wherein the Translocation Domain translocates the DNA sequence encoding the protease or protease fragment from within the endosome, across the endosomal membrane, and into the nociceptive sensory afferent cell.

25

In a preferred embodiment, the receptor is an ORL₁ receptor.

30 DNA encoding a protein of interest can be transfected into eukaryotic cells through receptor-mediated endocytosis of a protein-DNA conjugate, as confirmed by Cotton

et al. (Cotton, M., Wagner, E. and Birnstiel, L. (1993) Receptor-mediated transport of

DNA into eukaryotic cells. Methods in Enzymol. 217, 619-645). Several methods exist for condensing DNA to a suitable size using polycationic ligands. These include: polylysine, various cationic peptides and cationic liposomes. Of these, polylysine was used in the present study because of its successfully reported use in
5 receptor-mediated transfection studies (Cotton *et al.*, 1993).

The DNA sequence encoding the non-cytotoxic protease component may be expressed under the control of an operably linked promoter present as part of the agent (e.g. as part of the protease DNA sequence upstream of the coding region).
10 Alternatively, expression of the protease component in the target cell may rely on a promoter present in the target cell.

The DNA sequence encoding the protease component may integrate into a DNA sequence of the target cell. One or more integration site(s) may be provided as part
15 of the conjugate (e.g. as part of the protease DNA sequence).

The TM, Translocation Domain and protease components of this second aspect of the invention are as defined for the first aspect of the invention. Examples 13 and 14 describe the preparation of conjugates according to the second aspect of the
20 invention.

According to a third aspect, the present invention provides use of a pharmaceutical composition comprising a conjugate according to the first and/or second aspect of the present invention.
25

The pharmaceutical composition may further comprise a pharmaceutically-acceptable carrier, and/or a suitable diluent and/or excipient, although the exact form of the composition may be tailored to the mode of administration. Administration is preferably to a mammal, more preferably to a human.
30

The components of the composition may, for example, be employed in the form of an aerosol or nebulisable solution for inhalation or a sterile solution for parenteral

administration, intra-articular administration or intra-cranial administration.

The composition may also be administered by i.v. injection, which includes the use of pump systems. Spinal injection (e.g. epidural or intrathecal) or indwelling pumps
5 may also be used.

The dosage ranges for administration of the components of the present invention are those to produce the desired therapeutic effect. It will be appreciated that the dosage range required depends on the precise nature of the components, the route
10 of administration, the nature of the formulation, the age of the patient, the nature, extent or severity of the patient's condition, contraindications, if any, and the judgement of the attending physician.

Suitable daily dosages (for each component) are in the range 0.0001-1 mg/kg,
15 preferably 0.0001-0.5 mg/kg, more preferably 0.002-0.5 mg/kg, and particularly preferably 0.004-0.5 mg/kg. The unit dosage can vary from less than 1 microgram to 30 mg, but typically will be in the region of 0.01 to 1 mg per dose, which may be administered daily or preferably less frequently, such as weekly or six monthly.

20 A particularly preferred dosing regimen is based on 2.5 ng of fusion protein (e.g. CPNv/A) as the 1X dose. In this regard, preferred dosages are in the range 1X-100X (i.e. 2.5-250 ng). This dosage range is significantly lower (i.e. at least 10-fold, typically 100-fold lower) than would be employed with other types of analgesic molecules such as NSAIDS, morphine, and gabapentin. Moreover, the above-
25 mentioned difference is considerably magnified when the same comparison is made on a molar basis – this is because the fusion proteins of the present invention have a considerably greater Mw than do conventional 'small' molecule therapeutics.

Wide variations in the required dosage, however, are to be expected depending on
30 the precise nature of the components, and the differing efficiencies of various routes of administration. For example, oral administration would be expected to require higher dosages than administration by intravenous injection.

Variations in these dosage levels can be adjusted using standard empirical routines for optimisation, as is well understood in the art.

- 5 Compositions suitable for injection may be in the form of solutions, suspensions or emulsions, or dry powders which are dissolved or suspended in a suitable vehicle prior to use.

Fluid unit dosage forms are typically prepared utilising a pyrogen-free sterile vehicle.

10

The active ingredients, depending on the vehicle and concentration used, can be either dissolved or suspended in the vehicle.

- 15 Solutions may be used for all forms of parenteral administration, and are particularly used for intravenous injection. In preparing solutions the components can be dissolved in the vehicle, the solution being made isotonic if necessary by addition of sodium chloride and sterilised by filtration through a sterile filter using aseptic techniques before filling into suitable sterile vials or ampoules and sealing. Alternatively, if solution stability is adequate, the solution in its sealed containers
20 may be sterilised by autoclaving.

25

Advantageously additives such as buffering, solubilising, stabilising, preservative or bactericidal, suspending or emulsifying agents and/or local anaesthetic agents may be dissolved in the vehicle.

Dry powders which are dissolved or suspended in a suitable vehicle prior to use may be prepared by filling pre-sterilised drug substance and other ingredients into a sterile container using aseptic technique in a sterile area.

- 30 Alternatively the components of the composition may be dissolved in an aqueous vehicle, the solution is sterilized by filtration and distributed into suitable containers using aseptic technique in a sterile area. The product is then freeze-dried and the

containers are sealed aseptically.

Parenteral suspensions, suitable for intramuscular, subcutaneous or intradermal injection, are prepared in substantially the same manner, except that the sterile
5 components are suspended in the sterile vehicle, instead of being dissolved and sterilisation cannot be accomplished by filtration. The components may be isolated in a sterile state or alternatively it may be sterilised after isolation, e.g. by gamma irradiation.

10 Advantageously, a suspending agent for example polyvinylpyrrolidone is included in the composition(s) to facilitate uniform distribution of the components.

Compositions suitable for administration via the respiratory tract include aerosols, nebulisable solutions or microfine powders for insufflation. In the latter case, particle
15 size of less than 50 microns, especially less than 10 microns, is preferred. Such compositions may be made up in a conventional manner and employed in conjunction with conventional administration devices.

The compositions described in this invention can be used in vivo, either directly or as
20 a pharmaceutically acceptable salt, for the treatment of conditions involving exocytosis (for example secretion, or the delivery of proteins such as receptors, transporters, and membrane channels to the plasma membrane of a cell).

The present invention provides a DNA construct that encodes a conjugate according
25 to the first or second aspects of the invention.

By expressing the construct in a host cell, conjugates of the invention may be prepared.

30 The present invention provides a method for the treatment of particular types of pain by administration to a patient of a conjugate, composition, or construct of the invention, or any combination thereof.

Definitions Section

Exocytic fusion is a process by which intracellular molecules are transported from the cytosol of a pain-sensing target cell to the plasma (i.e. cell) membrane thereof. Thereafter, the intracellular molecules may become displayed on the outer surface of the plasma membrane, or may be secreted into the extracellular environment.

In a healthy individual, the rate of exocytic fusion is carefully regulated and allows control of the transport of molecules between the cytosol and the plasma membrane of a pain-sensing cell. For example, regulation of the exocytic cycle allows control of the density of receptors, transporters, or membrane channels present at the cell's surface, and/or allows control of the secretion rate of intracellular components (e.g. neurotransmitters) from the cytosol of the cell.

However, in an unhealthy individual, the regulation of exocytic fusion may be modified. For example, exocytic fusion may cause affected pain-sensing cells to enter a state of hypersecretion. Alternatively, exocytic fusion may result in the display of an increased concentration of receptors, transporters, or membrane channels present on the surface of the pain-sensing, which may expose the cell to undesirable external stimuli. Thus, the process of exocytic fusion may contribute to the progression and/or severity of pain, and therefore provides a target for therapeutic intervention.

It should also be appreciated that otherwise normal rates of cellular exocytic fusion may contribute to the progression and severity of pain in compromised patients. Thus, by targeting exocytic fusion in accordance with the present invention, it is also possible to provide therapy in such patients

Targeting Moiety (TM) means any chemical structure associated with a conjugate that functionally interacts with a receptor, e.g. an ORL₁ receptor, to cause a physical association between the conjugate and the surface of a pain-sensing target cell.

The term TM embraces any molecule (i.e. a naturally occurring molecule, or a chemically/physically modified variant thereof) that is capable of binding to a receptor on the target cell, which receptor is capable of internalisation (e.g. endosome formation) – also referred to as receptor-mediated endocytosis. The TM
5 may possess an endosomal membrane translocation domain, in which case separate TM and Translocation Domain components need not be present in an agent of the present invention.

The term “fragment” means a peptide having at least thirty-five, preferably at least
10 twenty-five, more preferably at least fifteen, and most preferably at least ten amino acid residues of the TM in question. In one embodiment, the first amino acid residue of the fragment is the N-terminal amino acid residue of the TM from which the fragment has been derived.

15 An example of a “variant” is a peptide or peptide fragment of a TM that contains one or more analogues of an amino acid (e.g. an unnatural amino acid), or a substituted linkage.

A “derivative” comprises the TM in question, and a further peptide sequence. The
20 further peptide sequence should preferably not interfere with the basic folding and thus conformational structure of the TM. Two or more peptides (or fragments, or variants) may be joined together to form a derivative. Alternatively, a peptide (or fragment, or variant) may be joined to an unrelated molecule (e.g. a second, unrelated peptide). Derivatives may be chemically synthesized, but will be typically
25 prepared by recombinant nucleic acid methods. Additional components such as lipid, and/or polysaccharide, and/or polyketide components may be included.

The term non-cytotoxic means that the protease molecule in question does not kill the pain-sensing target cell to which it has been re-targeted.

30

The “protease cleavage site” of the present invention allows cleavage (preferably controlled cleavage) of the conjugate at a position between the non-cytotoxic

protease component and the TM component. In one embodiment, the conjugate may include more than one proteolytic cleavage site. However, where two or more such sites exist, they are different, thereby substantially preventing the occurrence of multiple cleavage events in the presence of a single protease. In another
5 embodiment, it is preferred that the conjugate has a single protease cleavage site. The protease cleavage sequence(s) may be introduced (and/or any inherent cleavage sequence removed) at the DNA level by conventional means, such as by site-directed mutagenesis. Screening to confirm the presence of cleavage sequences may be performed manually or with the assistance of computer software
10 (e.g. the MapDraw program by DNASTAR, Inc.).

Whilst any protease cleavage site may be employed, the following are preferred:

	Enterokinase	(DDDDK↓)
15	Factor Xa	(IEGR↓ / IDGR↓)
	TEV(Tobacco Etch virus)	(ENLYFQ↓G)
	Thrombin	(LVPR↓GS)
	PreScission	(LEVLFQ↓GP).

20 Also embraced by the term protease cleavage site is an intein, which is a self-cleaving sequence. The self-splicing reaction is controllable, for example by varying the concentration of reducing agent present.

The present invention is now described by reference to the following Examples and
25 Figures, without intended limitation thereto.

Figures

- Figure 1 Expression and purification of *recLH_N/B* fusion protein
- 30 Figure 2 Expression and purification of *LH_N/C* fusion protein
- Figure 3 Expression and purification of *N[1-17]-LH_N/A* fusion protein
- Figure 4 Purification of a *LC/A-nociceptin-H_N/A* fusion-protein

- Figure 5 Purification of a nociceptin-LC/A-H_N/A fusion protein
- Figure 6 Purification of a LC/C-nociceptin-H_N/C fusion protein
- Figure 7 Purification of a LC/A-met enkephalin-H_N/A fusion protein
- Figure 8 Comparison of binding efficacy of a LC/A-nociceptin-H_N/A fusion protein and a nociceptin-LC/A-H_N/A fusion protein
- 5 Figure 9 *In vitro* catalytic activity of a LC/A-nociceptin-H_N/A fusion protein
- Figure 10 Purification of a LC/A-nociceptin variant-H_N/A fusion protein
- Figure 11 Comparison of binding efficacy of a LC/A-nociceptin-H_N/A fusion protein and a LC/A-nociceptin variant-H_N/A fusion protein
- 10 Figure 12 Expressed / purified LC/A-nociceptin-H_N/A fusion protein family with variable spacer length product(s)
- Figure 13 Inhibition of SP release and cleavage of SNAP-25 by CPN-A
- Figure 14 Inhibition of SP release and cleavage of SNAP-25 over extended time periods after exposure of DRG to CPN-A
- 15 Figure 15 Cleavage of SNAP-25 by CPNv-A
- Figure 16 Cleavage of SNAP-25 over extended time periods after exposure of DRG to CPNv-A
- Figure 17 CPNv-A fusion-mediated displacement of [3H]-nociceptin binding
- Figure 18 Expressed / purified CPNv(Ek)-A product
- 20 Figure 19 Cleavage of SNAP-25 by CPNv(Ek)-A
- Figure 20 Expressed / purified CPNv-C product
- Figure 21 Cleavage of syntaxin by CPNv-C
- Figure 22 CPN-A efficacy in the Acute Capsaicin-Induced Mechanical Allodynia model
- 25 Figure 23 CPN-A efficacy in the Streptozotocin (STZ)-Induced Peripheral Diabetic Neuropathy (Neuropathic Pain) model
- Figure 24 CPNv-A efficacy in the Acute Capsaicin-Induced Mechanical Allodynia model
- Figure 25 Expressed / purified LC/A-CPLE-H_N/A product
- 30 Figure 26 Expressed / purified LC/A-CPBE-H_N/A product
- Figure 27 Expressed / purified CPOP-A product
- Figure 28 Expressed / purified CPOPv-A product

- Figure 29 *In vitro* SNAP-25 cleavage in a DRG cell model
- Figure 30 Expressed / purified CPNv-A-FXa-HT (removable his-tag)
- Figure 31 *In vitro* efficacy of LC/A-nociceptin-H_N/A fusion proteins with variable spacer length, as assessed by ligand competition assay
- 5 Figure 32 *In vitro* efficacy of LC/A-nociceptin-H_N/A fusion proteins with variable spacer length, as assessed by *in vitro* SNAP-25 cleavage

The Figures are now described in more detail.

10 **Figure 1 - Expression and purification of *rec*LH_N/B fusion protein**

SDS-PAGE analysis of expression and purification of *rec*LH_N/B from *E. coli*. In Figure1, *rec*LH_N/B is purified from cell paste using a three column strategy as described in Example 3. Protein samples are separated by SDS-PAGE and

15 visualised by staining with simplyblue safestain coomassie reagent. Crude, soluble MBP-LH_N/B fusion protein contained within the clarified extract (lane 2) is loaded onto Q-Sepharose FF anion-exchange resin. Lane 3 represents recombinant MBP-LH_N/B fusion eluted from column at 150-200 mM salt. This sample is treated with factor Xa protease to remove MBP affinity tag (lane 4), and cleaved mixture diluted

20 to lower salt concentration prior to loading onto a Q-Sepharose FF anion-exchange column. Material eluted between 120-170 mM salt was rich in LH_N/B (lane 5). Protein in lanes 6 and 8 represents LH_N/B harvested after treatment with enterokinase and final purification using Benzamidine Sepharose, under non-reducing and reducing conditions respectively. Lanes 1 and 7 represent molecular

25 mass markers [Mark 12 (Invitrogen)].

Figure 2 - Expression and purification of LH_N/C fusion protein

SDS-PAGE analysis of expression and purification of LH_N/C from *E. coli*. In Figure

30 2, *rec*LH_N/C is purified from *E. coli* cell paste using a two-step strategy described in Example 4. Protein samples are separated by SDS-PAGE and visualised by staining with coomassie blue. Clarified Crude cell lysate (lane 2) is loaded onto Q-

Sepharose FF anion-exchange resin. Fusion protein, MBP-LH_N/C is eluted with 0.1 M NaCl (lane 3). Eluted material incubated at 22°C for 16 h with factor Xa protease (New England Biolabs) to cleave fusion tag MBP and nick recLH_N/C at the linker site.

The protein of interest is further purified from cleaved fusion products (lane 4) using Q-Sepharose FF. Lanes 5 and 7 show purified recLH_N/C under non-reducing conditions and reduced with 10 mM DTT respectively, to illustrate disulphide bonding at the linker region between LC and H_N domains after nicking with factor Xa. Lanes 1 and 6 represent molecular mass markers (shown in KDa); Mark 12 (Invitrogen).

10 **Figure 3 - Expression and purification of N[1-17]-LH_N/A fusion protein**

SDS-PAGE analysis of expression and purification of N[1-17]-LH_N/A from *E. coli*. In Figure 3, N[1-17]-LH_N/A is purified from *E. coli* BL21 cell paste using the methodology outlined in Example 9. Briefly, the soluble products obtained following cell disruption were applied to a nickel-charged affinity capture column. Bound proteins were eluted with 100 mM imidazole, treated with Factor Xa to activate the fusion protein and remove the maltose-binding protein (MBP) tag, then re-applied to a second nickel-charged affinity capture column. Samples from the purification procedure were assessed by SDS-PAGE (Panel A) and Western blotting (Panel B). Anti-nociceptin antisera (obtained from Abcam) were used as the primary antibody for Western blotting. The final purified material in the absence and presence of reducing agent is identified in the lanes marked [-] and [+] respectively.

25 **Figure 4 - Purification of a LC/A-nociceptin-H_N/A fusion protein**

Using the methodology outlined in Example 26, a LC/A-nociceptin-H_N/A fusion protein was purified from *E. coli* BL21 cells. Briefly, the soluble products obtained following cell disruption were applied to a nickel-charged affinity capture column. Bound proteins were eluted with 100 mM imidazole, treated with Factor Xa to activate the fusion protein and remove the maltose-binding protein (MBP) tag, then re-applied to a second nickel-charged affinity capture column. Samples from the purification procedure were assessed by SDS-PAGE (Panel A) and Western blotting.

(Panel B). Anti-nociceptin antisera (obtained from Abcam) were used as the primary antibody for Western blotting. The final purified material in the absence and presence of reducing agent is identified in the lanes marked [-] and [+] respectively.

5 **Figure 5 - Purification of a nociceptin-LC/A-H_N/A fusion protein**

Using the methodology outlined in Example 26, a nociceptin-LC/A-H_N/A fusion protein was purified from *E. coli* BL21 cells. Briefly, the soluble products obtained following cell disruption were applied to a nickel-charged affinity capture column.

10 Bound proteins were eluted with 100 mM imidazole, treated with Factor Xa to activate the fusion protein and remove the maltose-binding protein (MBP) tag, then re-applied to a second nickel-charged affinity capture column. Samples from the purification procedure were assessed by SDS-PAGE (Panel A) and Western blotting (Panel B). Anti-nociceptin antisera (obtained from Abcam) were used as the primary
15 antibody for Western blotting. The final purified material in the absence and presence of reducing agent is identified in the lanes marked [-] and [+] respectively.

Figure 6 - Purification of a LC/C-nociceptin-H_N/C fusion protein

20 Using the methodology outlined in Example 26, an LC/C-nociceptin-H_N/C fusion protein was purified from *E. coli* BL21 cells. Briefly, the soluble products obtained following cell disruption were applied to a nickel-charged affinity capture column. Bound proteins were eluted with 100 mM imidazole, treated with Factor Xa to activate the fusion protein and remove the maltose-binding protein (MBP) tag, then
25 re-applied to a second nickel-charged affinity capture column. Samples from the purification procedure were assessed by SDS-PAGE (Panel A) and Western blotting (Panel B). Anti-nociceptin antisera (obtained from Abcam) were used as the primary antibody for Western blotting. The final purified material in the absence and presence of reducing agent is identified in the lanes marked [-] and [+] respectively.

Figure 7 - Purification of a LC/A-met enkephalin-H_N/A fusion protein

Using the methodology outlined in Example 26, an LC/A-met enkephalin-H_N/A fusion
5 protein was purified from *E. coli* BL21 cells. Briefly, the soluble products obtained
following cell disruption were applied to a nickel-charged affinity capture column.
Bound proteins were eluted with 100 mM imidazole, treated with Factor Xa to
activate the fusion protein and remove the maltose-binding protein (MBP) tag, then
re-applied to a second nickel-charged affinity capture column. Samples from the
10 purification procedure were assessed by SDS-PAGE. The final purified material in
the absence and presence of reducing agent is identified in the lanes marked [-] and
[+] respectively.

Figure 8 - Comparison of binding efficacy of a LC/A-nociceptin-H_N/A fusion 15 protein and a nociceptin-LC/A-H_N/A fusion protein

The ability of nociceptin fusions to bind to the ORL₁ receptor was assessed using a
simple competition-based assay. Primary cultures of dorsal root ganglia (DRG) were
exposed to varying concentrations of test material in the presence of 1 nM [3H]-
20 nociceptin. The reduction in specific binding of the radiolabelled ligand was
assessed by scintillation counting, and plotted in comparison to the efficacy of
unlabelled ligand (Tocris nociceptin). It is clear that the LC/A-nociceptin-H_N/A fusion
is far superior to the nociceptin-LC/A-H_N/A fusion at interacting with the ORL₁
receptor.

25

Figure 9 - *In vitro* catalytic activity of a LC/A-nociceptin-H_N/A fusion protein

The *in vitro* endopeptidase activity of the purified LC/A-nociceptin-H_N/A fusion
protein was determined essentially as described in Chaddock *et al* 2002, Prot.
30 Express Purif. 25, 219-228. Briefly, SNAP-25 peptide immobilised to an ELISA plate
was exposed to varying concentrations of fusion protein for 1 hour at 37°C.

Following a series of washes, the amount of cleaved SNAP-25 peptide was quantified by reactivity with a specific antisera.

Figure 10 - Purification of a LC/A-nociceptin variant-H_N/A fusion protein

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Using the methodology outlined in Example 26, an LC/A-nociceptin variant-H_N/A fusion protein was purified from *E. coli* BL21 cells. Briefly, the soluble products obtained following cell disruption were applied to a nickel-charged affinity capture column. Bound proteins were eluted with 100 mM imidazole, treated with Factor Xa to activate the fusion protein and remove the maltose-binding protein (MBP) tag, then re-applied to a second nickel-charged affinity capture column. Samples from the purification procedure were assessed by SDS-PAGE. The final purified material in the absence and presence of reducing agent is identified in the lanes marked [-] and [+] respectively.

15

Figure 11 - Comparison of binding efficacy of a LC/A-nociceptin-H_N/A fusion protein and a LC/A-nociceptin variant-H_N/A fusion protein

The ability of nociceptin fusions to bind to the ORL₁ receptor was assessed using a simple competition-based assay. Primary cultures of dorsal root ganglia (DRG) were exposed to varying concentrations of test material in the presence of 1nM [3H]-nociceptin. The reduction in specific binding of the radiolabelled ligand was assessed by scintillation counting, and plotted in comparison to the efficacy of unlabelled ligand (Tocris nociceptin). It is clear that the LC/A-nociceptin variant-H_N/A fusion (CPNv-LHA) is superior to the LC/A-nociceptin variant-H_N/A fusion (CPN-LHA) at interacting with the ORL₁ receptor.

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Figure 12 - Expressed / purified LC/A-nociceptin-H_N/A fusion protein family with variable spacer length product(s)

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Using the methodology outlined in Example 26, variants of the LC/A-CPN-H_N/A fusion consisting of GS10, GS30 and HX27 are purified from *E. coli* cell paste.

Samples from the purification of LC/A-CPN(GS10)-H_N/A, LC/A-CPN(GS15)-H_N/A, LC/A-CPN(GS25)-H_N/A, LC/A-CPN(GS30)-H_N/A and LC/A-CPN(HX27)-H_N/A were assessed by SDS-PAGE prior to staining with Coomassie Blue. The electrophoresis profile indicates purification of a disulphide-bonded di-chain species of the expected molecular mass of CPBE-A. Top panel: M = benchmark molecular mass markers; S = total *E. coli* protein soluble fraction; FT = proteins that did not bind to the Ni²⁺-charged Sepharose column; FUSION = fusion protein eluted by the addition of imidazole. Bottom panel: Lane 1 = benchmark molecular mass markers; Lane 2 = total *E. coli* protein soluble fraction; Lane 3 = purified material following initial capture on Ni²⁺-charged Sepharose; Lane 4 = Factor Xa treated material prior to final capture on Ni²⁺-charged Sepharose; Lane 5 = purified final material post activation with Factor Xa (5 µl); Lane 6 = purified final material post activation with Factor Xa (10 µl); Lane 7 = purified final material post activation with Factor Xa (20 µl); Lane 8 = purified final material post activation with Factor Xa + DTT (5 µl); Lane 9 = purified final material post activation with Factor Xa + DTT (10 µl); Lane 10 = purified final material post activation with Factor Xa + DTT (20 µl).

Figure 13 - Inhibition of SP release and cleavage of SNAP-25 by CPN-A

Briefly, primary cultures of dorsal root ganglia (DRG) were exposed to varying concentrations of CPN-A for 24 hours. Cellular proteins were separated by SDS-PAGE, Western blotted, and probed with anti-SNAP-25 to facilitate an assessment of SNAP-25 cleavage. The percentage of cleaved SNAP-25 was calculated by densitometric analysis and plotted against fusion concentration (dashed line). Material was also recovered for an analysis of substance P content using a specific EIA kit. Inhibition of substance P release is illustrated by the solid line. The fusion concentration required to achieve 50% maximal SNAP-25 cleavage is estimated to be 6.30±2.48 nM.

Figure 14 - Inhibition of SP release and cleavage of SNAP-25 over extended time periods after exposure of DRG to CPN-A

Primary cultures of dorsal root ganglia (DRG) were exposed to varying concentrations of CPN-A for 24 hours. Botulinum neurotoxin (BoNT/A) was used as a control. After this initial exposure, extracellular material was removed by washing, and the cells incubated at 37°C for varying periods of time. At specific time points, cellular proteins were separated by SDS-PAGE, Western blotted, and probed with anti-SNAP-25 to facilitate an assessment of SNAP-25 cleavage. The percentage of cleaved SNAP-25 was calculated by densitometric analysis and illustrated by the dotted lines. Material was also recovered for an analysis of substance P content using a specific EIA kit. Inhibition of substance P release is illustrated by the solid lines.

Figure 15 - Cleavage of SNAP-25 by CPNv-A

Primary cultures of dorsal root ganglia (DRG) were exposed to varying concentrations of CPNv-A for 24 hours. Cellular proteins were separated by SDS-PAGE, Western blotted, and probed with anti-SNAP-25 to facilitate an assessment of SNAP-25 cleavage. The percentage of cleaved SNAP-25 was calculated by densitometric analysis. The fusion concentration required to achieve 50% maximal SNAP-25 cleavage is estimated to be 1.38 ± 0.36 nM.

Figure 16 - Cleavage of SNAP-25 over extended time periods after exposure of DRG to CPNv-A

Primary cultures of dorsal root ganglia (DRG) were exposed to varying concentrations of CPNv-A for 24 hours. CPN-A was used as a control. After this initial exposure, extracellular material was removed by washing, and the cells incubated at 37°C for varying periods of time. At specific time points, cellular proteins were separated by SDS-PAGE, Western blotted, and probed with anti-SNAP-25 to facilitate an assessment of SNAP-25 cleavage. The percentage of

cleaved SNAP-25 was calculated by densitometric analysis.

Figure 17 - CPNv-A fusion-mediated displacement of [3H]-nociceptin binding

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The ability of nociceptin fusions to bind to the ORL₁ receptor was assessed using a simple competition-based assay. Primary cultures of dorsal root ganglia (DRG) were exposed to varying concentrations of test material in the presence of 1 nM [3H]-nociceptin. The reduction in specific binding of the radiolabelled ligand was assessed by scintillation counting, and plotted in comparison to the efficacy of unlabelled ligand (Tocris nociceptin). It is clear that the LC/A-nociceptin variant-H_N/A fusion (labelled as CPNv-LHnA) is superior to the LC/A-nociceptin-H_N/A fusion (labelled as CPN-LHnA) at interacting with the ORL₁ receptor.

Figure 18 - Expressed / purified CPNv(Ek)-A product

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Proteins were subjected to SDS-PAGE prior to staining with Coomassie Blue. The electrophoresis profile indicates purification of a disulphide-bonded di-chain species of the expected molecular mass of CPNv(Ek)-A. Lane 1 = benchmark molecular mass markers; Lane 2 = total *E. coli* protein soluble fraction; Lane 3 = purified material following initial capture on Ni²⁺-charged Sepharose; Lane 4 = purified final material post activation with enterokinase (5 µl); Lane 5 = purified final material post activation with enterokinase (10 µl); Lane 6 = purified final material post activation with enterokinase (20 µl); Lane 7 = purified final material post activation with enterokinase + DTT (5 µl); Lane 8 = purified final material post activation with enterokinase + DTT (10 µl); Lane 9 = purified final material post activation with enterokinase + DTT (20 µl).

25

Figure 19 - Cleavage of SNAP-25 by CPNv(Ek)-A

30

Primary cultures of dorsal root ganglia (DRG) were exposed to varying concentrations of CPNv(Ek)-A for 24 hours. Cellular proteins were separated by

SDS-PAGE, Western blotted, and probed with anti-SNAP-25 to facilitate an assessment of SNAP-25 cleavage. The percentage of cleaved SNAP-25 was calculated by densitometric analysis. CPNv-A as prepared in Example 26 was used for comparison purposes. The percentage cleavage of SNAP-25 by CPNv(Ek)-A (labelled as En activated) and CPNv-A (labelled as Xa activated) are illustrated.

Figure 20 - Expressed / purified CPNv-C product

Proteins were subjected to SDS-PAGE prior to staining with Coomassie Blue. The electrophoresis profile indicates purification of a disulphide-bonded di-chain species of the expected molecular mass of CPNv-C. Lane 1 = benchmark molecular mass markers; Lane 2 = total *E. coli* protein soluble fraction; Lane 3 = purified material following initial capture on Ni^{2+} -charged Sepharose; Lane 4 = Factor Xa treated material prior to final capture on Ni^{2+} -charged Sepharose; Lane 5 = purified material following second capture on Ni^{2+} -charged Sepharose; Lane 6 = final purified material; Lane 7 = final purified material + DTT; Lane 8 = benchmark molecular mass markers.

Figure 21 - Cleavage of syntaxin by CPNv-C

Primary cultures of dorsal root ganglia (DRG) were exposed to varying concentrations of CPNv-C for 24 hours. Cellular proteins were separated by SDS-PAGE, Western blotted, and probed with anti-syntaxin to facilitate an assessment of syntaxin cleavage. The percentage of cleaved syntaxin was calculated by densitometric analysis. The fusion concentration required to achieve 50% maximal syntaxin cleavage is estimated to be 3.13 ± 1.96 nM.

Figure 22 - CPN-A efficacy in the Acute Capsaicin-Induced Mechanical Allodynia model

The ability of an LC/A-nociceptin- H_N /A fusion (CPN/A) to inhibit capsaicin-induced mechanical allodynia was evaluated following subcutaneous intraplantar injection in

the rat hind paw. Test animals were evaluated for paw withdrawal frequency (PWF%) in response to a 10 g Von Frey filament stimulus series (10 stimuli x 3 trials) prior to recruitment into the study (Pre-Treat); after subcutaneous intraplantar treatment with CPN/A but before capsaicin (Pre-CAP); and following capsaicin challenge post-injection of CPN/A (average of responses at 15' and 30'; CAP). Capsaicin challenge was achieved by injection of 10 μ L of a 0.3% solution. Sample dilutions were prepared in 0.5% BSA/saline.

Figure 23 - CPN-A efficacy in the Streptozotocin (STZ)-Induced Peripheral Diabetic Neuropathy (Neuropathic Pain) model

Male Sprague-Dawley rats (250-300 g) are treated with 65 mg/kg STZ in citrate buffer (I.V.) and blood glucose and lipid are measured weekly to define the readiness of the model. Paw Withdrawal Threshold (PWT) is measured in response to a Von Frey filament stimulus series over a period of time. Allodynia is said to be established when the PWT on two consecutive test dates (separated by 1 week) measures below 6 g on the scale. At this point, rats are randomized to either a saline group (negative efficacy control), gabapentin group (positive efficacy control) or a test group (CPN/A). Test materials (20-25 μ l) are injected subcutaneously as a single injection (except gabapentin) and the PWT is measured at 1 day post-treatment and periodically thereafter over a 2 week period. Gabapentin (30 mg/kg i.p. @ 3 ml/kg injection volume) is injected daily, 2 hours prior to the start of PWT testing.

Figure 24 - CPNv-A efficacy in the Acute Capsaicin-Induced Mechanical Allodynia model

The ability of an LC/A-nociceptin variant-H_N/A fusion (CPNv/A) to inhibit capsaicin-induced mechanical allodynia was evaluated following subcutaneous intraplantar injection in the rat hind paw. Test animals were evaluated for paw withdrawal frequency (PWF%) in response to a 10 g Von Frey filament stimulus series (10 stimuli x 3 trials) prior to recruitment into the study (Pre-Treat); after subcutaneous

intraplantar treatment with CPNv/A but before capsaicin (Pre-CAP), and following capsaicin challenge post-injection of CPNv/A (average of responses at 15' and 30'; CAP). Capsaicin challenge was achieved by injection of 10 μ L of a 0.3% solution. Sample dilutions were prepared in 0.5% BSA/saline. These data are expressed as a
5 normalized paw withdrawal frequency differential, in which the difference between the peak response (post-capsaicin) and the baseline response (pre-capsaicin) is expressed as a percentage. With this analysis, it can be seen that CPNv/A is more potent than CPN/A since a lower dose of CPNv/A is required to achieve similar analgesic effect to that seen with CPN/A.

10

Figure 25 - Expressed / purified LC/A-CPLE-H_N/A product

Proteins were subjected to SDS-PAGE prior to staining with Coomassie Blue. The electrophoresis profile indicates purification of a disulphide-bonded di-chain species
15 of the expected molecular mass of CPLE-A. Lane 1 = benchmark molecular mass markers; Lane 2 = total *E. coli* protein soluble fraction; Lane 3 = purified material following initial capture on Ni²⁺-charged Sepharose; Lane 4 = Factor Xa treated material prior to final capture on Ni²⁺-charged Sepharose; Lane 5 = purified material following second capture on Ni²⁺-charged Sepharose; Lane 6 = final purified
20 material; Lane 7 = final purified material + DTT.

Figure 26 - Expressed / purified LC/A-CPBE-H_N/A product

Proteins were subjected to SDS-PAGE prior to staining with Coomassie Blue. The
25 electrophoresis profile indicates purification of a disulphide-bonded di-chain species of the expected molecular mass of CPBE-A. Lane 1 = total *E. coli* protein soluble fraction; Lane 2 = purified material following initial capture on Ni²⁺-charged Sepharose; Lane 3 = Factor Xa treated material prior to final capture on Ni²⁺-charged Sepharose; Lane 4 = purified final material post activation with Factor Xa (5
30 μ l); Lane 5 = purified final material post activation with Factor Xa (10 μ l); Lane 6 = purified final material post activation with Factor Xa (20 μ l); Lane 7 = purified final material post activation with Factor Xa + DTT (5 μ l); Lane 8 = purified final material

post activation with Factor Xa + DTT (10 μ l); Lane 9 = purified final material post activation with Factor Xa + DTT (20 μ l); Lane 10 = benchmark molecular mass markers.

5 **Figure 27 - Expressed / purified CPOP-A product**

Proteins were subjected to SDS-PAGE prior to staining with Coomassie Blue. The electrophoresis profile indicates purification of a disulphide-bonded di-chain species of the expected molecular mass of CPOP-A. Lane 1 = benchmark molecular mass
 10 markers; Lane 2 = purified material following initial capture on Ni^{2+} -charged Sepharose; Lane 3 = Factor Xa treated material prior to final capture on Ni^{2+} -charged Sepharose; Lane 4 = purified material following second capture on Ni^{2+} -charged Sepharose; Lane 5 = purified final material post activation with Factor Xa (5 μ l); Lane 6 = purified final material post activation with Factor Xa (10 μ l); Lane 7 =
 15 purified final material post activation with Factor Xa (20 μ l); Lane 8 = purified final material post activation with Factor Xa + DTT (5 μ l); Lane 9 = purified final material post activation with Factor Xa + DTT (10 μ l); Lane 10 = purified final material post activation with Factor Xa + DTT (20 μ l).

20 **Figure 28 - Expressed / purified CPOPv-A product**

Proteins were subjected to SDS-PAGE prior to staining with Coomassie Blue. The electrophoresis profile indicates purification of a disulphide-bonded di-chain species of the expected molecular mass of CPOPv-A. Lane 1 = benchmark molecular mass
 25 markers; Lane 2 = total *E. coli* protein soluble fraction; Lane 3 = purified material following initial capture on Ni^{2+} -charged Sepharose; Lane 4 = Factor Xa treated material prior to final capture on Ni^{2+} -charged Sepharose; Lane 5 = purified final material post activation with Factor Xa (5 μ l); Lane 6 = purified final material post activation with Factor Xa (10 μ l); Lane 7 = purified final material post activation with
 30 Factor Xa (20 μ l); Lane 8 = purified final material post activation with Factor Xa + DTT (5 μ l); Lane 9 = purified final material post activation with Factor Xa + DTT (10 μ l); Lane 10 = purified final material post activation with Factor Xa + DTT (20 μ l).

Figure 29 - *In vitro* SNAP-25 cleavage in a DRG cell model

5 Primary cultures of dorsal root ganglia (DRG) were exposed to varying concentrations of CPOPv-A for 24 hours. Cellular proteins were separated by SDS-PAGE, Western blotted, and probed with anti-SNAP-25 to facilitate an assessment of SNAP-25 cleavage. The percentage of cleaved SNAP-25 was calculated by densitometric analysis.

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Figure 30 - Expressed / purified CPNv-A-FXa-HT (removable his-tag)

Proteins were subjected to SDS-PAGE prior to staining with Coomassie Blue. The electrophoresis profile indicates purification of a disulphide-bonded di-chain species
15 of the expected molecular mass of CPNv-A-FXa-HT. Lane 1 = benchmark molecular mass markers; Lane 2 = total *E. coli* protein soluble fraction; Lane 3 = Factor Xa treated material prior to final capture on Ni²⁺-charged Sepharose; Lane 4 = purified final material post activation with Factor Xa; Lane 5 = purified final material post activation with Factor Xa + DTT.

20

Figure 31 - *In vitro* efficacy of LC/A-nociceptin-H_N/A fusion proteins with variable spacer length, as assessed by ligand competition assay

The ability of LC/A-nociceptin-H_N/A fusions of variable spacer length to bind to the
25 ORL₁ receptor was assessed using a simple competition-based assay. Primary cultures of dorsal root ganglia (DRG) were exposed to varying concentrations of test material in the presence of 1 nM [3H]-nociceptin. The reduction in specific binding of the radiolabelled ligand was assessed by scintillation counting, and plotted in comparison to the efficacy of unlabelled ligand (Tocris nociceptin). The upper panel
30 illustrates the displacement characteristics of the GS0, GS20, GS30 and Hx27 spacers, whilst the lower panel illustrates the displacement achieved by the GS10, GS15 and GS25 spaced fusion proteins. It is concluded that the GS0 and GS30

spacers are ineffective, and the GS10 is poorly effective, at displacing nociceptin from the ORL1 receptor.

Figure 32 - *In vitro* efficacy of LC/A-nociceptin-H_N/A fusion proteins with variable spacer length, as assessed by *in vitro* SNAP-25 cleavage

Primary cultures of dorsal root ganglia (DRG) were exposed to varying concentrations of CPN-A (of variable spacer length) for 24 hours. Cellular proteins were separated by SDS-PAGE, Western blotted, and probed with anti-SNAP-25 to facilitate an assessment of SNAP-25 cleavage. The percentage of cleaved SNAP-25 was calculated by densitometric analysis. The poorly effective binding characteristics of the GS10 spaced fusion protein (see Figure 28) are reflected in the higher concentrations of fusion required to achieve cleavage of intracellular SNAP-25. GS0 and GS30 spaced fusion proteins were completely ineffective (date not shown). GS15, 20 and 25 spaced fusion proteins were similarly effective.

SEQ ID Nos

	SEQ ID1	DNA sequence of N[1-17]
20	SEQ ID2	Protein Sequence of N[1-17]
	SEQ ID3	DNA sequence of N[1-11]
	SEQ ID4	Protein sequence of N[1-11]
	SEQ ID5	DNA sequence of N[[Y10]1-11]
	SEQ ID6	Protein sequence of N[[Y10]1-11]
25	SEQ ID7	DNA sequence of N[[Y11]1-11]
	SEQ ID8	Protein sequence of N[[Y11]1-11]
	SEQ ID9	DNA sequence of N[[Y14]1-17]
	SEQ ID10	Protein sequence of N[[Y14]1-17]
	SEQ ID11	DNA sequence of N[1-13]
30	SEQ ID12	Protein sequence of N[1-13]
	SEQ ID13	DNA sequence of Nv (also known as N[[R14K15]1-17])
	SEQ ID14	Protein sequence of Nv (also known as N[[R14K15]1-17])

	SEQ ID15	DNA sequence of N[1-17]-LH _N /A fusion protein
	SEQ ID16	Protein sequence of N[1-17]-LH _N /A fusion protein
	SEQ ID17	DNA sequence of N[[Y11]1-11]-LHN/A fusion protein
	SEQ ID18	Protein sequence of N[[Y11]1-11]-LHN/A fusion protein
5	SEQ ID19	DNA sequence of N[1-13]-LHN/A fusion protein
	SEQ ID20	Protein sequence of N[1-13]-LHN/A fusion protein
	SEQ ID21	DNA sequence of LHN/A-N[1-17] fusion protein
	SEQ ID22	Protein sequence of LHN/A-N[1-17] fusion protein
	SEQ ID23	DNA sequence of LHN/C-N[1-11] fusion protein
10	SEQ ID24	Protein sequence of LHN/C-N[1-11] fusion protein
	SEQ ID25	DNA sequence of N[[Y14]1-17]-LHN/C fusion protein
	SEQ ID26	Protein sequence of N[[Y14]1-17]-LHN/C fusion protein
	SEQ ID27	DNA sequence of the LC/A
	SEQ ID28	DNA sequence of the H _N /A
15	SEQ ID29	DNA sequence of the LC/B
	SEQ ID30	DNA sequence of the H _N /B
	SEQ ID31	DNA sequence of the LC/C
	SEQ ID32	DNA sequence of the H _N /C
	SEQ ID33	DNA sequence of the CPN-A linker
20	SEQ ID34	DNA sequence of the A linker
	SEQ ID35	DNA sequence of the N-terminal presentation nociceptin insert
	SEQ ID36	DNA sequence of the CPN-C linker
	SEQ ID37	DNA sequence of the CPBE-A linker
	SEQ ID38	DNA sequence of the CPNvar-A linker
25	SEQ ID39	DNA sequence of the LC/A-CPN-H _N /A fusion
	SEQ ID40	Protein sequence of the LC/A-CPN-H _N /A fusion
	SEQ ID41	DNA sequence of the N-LC/A-H _N /A fusion
	SEQ ID42	Protein sequence of the N-LC/A-H _N /A fusion
	SEQ ID43	DNA sequence of the LC/C-CPN-H _N /C fusion
30	SEQ ID44	Protein sequence of the LC/C-CPN-H _N /C fusion
	SEQ ID45	DNA sequence of the LC/C-CPN-H _N /C (A-linker) fusion
	SEQ ID46	Protein sequence of the LC/C-CPN-H _N /C (A-linker) fusion

- SEQ ID47 DNA sequence of the LC/A-CPME-H_N/A fusion
- SEQ ID48 Protein sequence of the LC/A-CPME-H_N/A fusion
- SEQ ID49 DNA sequence of the LC/A-CPBE-H_N/A fusion
- SEQ ID50 Protein sequence of the LC/A-CPBE-H_N/A fusion
- 5 SEQ ID51 DNA sequence of the LC/A-CPNv-H_N/A fusion
- SEQ ID52 Protein sequence of the LC/A-CPNv-H_N/A fusion
- SEQ ID53 DNA sequence of the LC/A-CPN[1-11]-HN/A fusion
- SEQ ID54 Protein sequence of the LC/A-CPN[1-11]-HN/A fusion
- SEQ ID55 DNA sequence of the LC/A-CPN[[Y10]1-11]-HN/A fusion
- 10 SEQ ID56 Protein sequence of the LC/A-CPN[[Y10]1-11]-HN/A fusion
- SEQ ID57 DNA sequence of the LC/A-CPN[[Y11]1-11]-HN/A fusion
- SEQ ID58 Protein sequence of the LC/A-CPN[[Y11]1-11]-HN/A fusion
- SEQ ID59 DNA sequence of the LC/A-CPN[[Y14]1-17]-HN/A fusion
- SEQ ID60 Protein sequence of the LC/A-CPN[[Y14]1-17]-HN/A fusion
- 15 SEQ ID61 DNA sequence of the LC/A-CPN[1-13]-HN/A fusion
- SEQ ID62 Protein sequence of the LC/A-CPN[1-13]-HN/A fusion
- SEQ ID63 DNA sequence of the nociceptin-spacer-LC/A-H_N/A fusion
- SEQ ID64 Protein sequence of the nociceptin-spacer-LC/A-H_N/A fusion
- SEQ ID65 DNA sequence of the CPN-A GS10 linker
- 20 SEQ ID66 DNA sequence of the CPN-A GS15 linker
- SEQ ID67 DNA sequence of the CPN-A GS25 linker
- SEQ ID68 DNA sequence of the CPN-A GS30 linker
- SEQ ID69 DNA sequence of the CPN-A HX27 linker
- SEQ ID70 DNA sequence of the LC/A-CPN(GS15)-H_N/A fusion
- 25 SEQ ID71 Protein sequence of the LC/A-CPN(GS15)-H_N/A fusion
- SEQ ID72 DNA sequence of the LC/A-CPN(GS25)-H_N/A fusion
- SEQ ID73 Protein sequence of the LC/A-CPN(GS25)-H_N/A fusion
- SEQ ID74 DNA sequence of the CPNvar-A Enterokinase activatable linker
- SEQ ID75 DNA sequence of the LC/A-CPNv(Ek)-H_N/A fusion
- 30 SEQ ID76 Protein sequence of the LC/A-CPNv(Ek)-H_N/A fusion
- SEQ ID77 DNA sequence of the CPNvar-A linker
- SEQ ID78 DNA sequence of the LC/C-CPNv-H_N/C fusion (act. A)

- SEQ ID79 Protein sequence of the LC/C-CPNV-H_N/C fusion (act. A)
SEQ ID80 DNA sequence of the LC/A-CPLE-H_N/A fusion
SEQ ID81 Protein sequence of the LC/A-CPLE-H_N/A fusion
SEQ ID82 DNA sequence of the LC/A-CPOP-H_N/A fusion
5 SEQ ID83 Protein sequence of the LC/A-CPOP-H_N/A fusion
SEQ ID84 DNA sequence of the LC/A-CPOPv-H_N/A fusion
SEQ ID85 Protein sequence of the LC/A-CPOPv-H_N/A fusion
SEQ ID86 DNA sequence of the IgA protease
SEQ ID87 DNA sequence of the IgA-CPNV-H_N/A fusion
10 SEQ ID88 Protein sequence of the IgA-CPNV-H_N/A fusion
SEQ ID89 DNA sequence of the FXa-HT
SEQ ID90 DNA sequence of the CPNV-A-FXa-HT
SEQ ID91 Protein sequence of the CPNV-A-FXa-HT fusion
SEQ ID92 DNA sequence of the DT translocation domain
15 SEQ ID93 DNA sequence of the CPLE-DT-A
SEQ ID94 Protein sequence of the CPLE-DT-A fusion
SEQ ID95 DNA sequence of the TeNT LC
SEQ ID96 DNA sequence of the CPNV-TENT LC
SEQ ID97 Protein sequence of the CPNV-TeNT LC fusion
20 SEQ ID98 DNA sequence of the CPNvar-C linker
SEQ ID99 DNA sequence of the LC/C-CPNV-H_N/C fusion (act. C)
SEQ ID100 Protein sequence of the LC/C-CPNV-H_N/C fusion (act. C)

25 **Examples**

Example 1 – Confirmation of TM Agonist Activity by measuring release of substance P from neuronal cell cultures

30 ***Materials***

Substance P EIA is obtained from R&D Systems, UK.

Methods

Primary neuronal cultures of eDRG are established as described previously (Duggan *et al.*, 2002). Substance P release from the cultures is assessed by EIA, essentially as described previously (Duggan *et al.*, 2002). The TM of interest is added to the neuronal cultures (established for at least 2 weeks prior to treatment); control cultures are performed in parallel by addition of vehicle in place of TM. Stimulated (100 mM KCl) and basal release, together with total cell lysate content, of substance P are obtained for both control and TM treated cultures. Substance P immunoreactivity is measured using Substance P Enzyme Immunoassay Kits (Cayman Chemical Company, USA or R&D Systems, UK) according to manufacturers' instructions.

The amount of Substance P released by the neuronal cells in the presence of the TM of interest is compared to the release obtained in the presence and absence of 100 mM KCl. Stimulation of Substance P release by the TM of interest above the basal release, establishes that the TM of interest is an "agonist ligand" as defined in this specification. If desired the stimulation of Substance P release by the TM of interest can be compared to a standard Substance P release-curve produced using the natural ORL-1 receptor ligand, nociceptin (Tocris).

Example 2 - Expression and purification of catalytically active LH_N/A

Materials

Synthetic DNA obtained from Sigma Genosys.
Restriction enzymes obtained from New England Biolabs.

Methods

The expression and purification of catalytically active LH_N/A was carried out essentially as described in Sutton *et al.*, (2005), Prot. Express. Purif., 40, pp 31-41.

Briefly, DNA encoding the light chain plus 423 amino acids from the N-terminal of the heavy chain of BoNT/A was synthesised by Sigma-Genosys to produce a synthetic

LH_N/A gene with an *E. coli* codon bias. The linker region between the light chain and H_N domain was engineered to contain a Factor Xa cleavage site by splice-overlap extension PCR. Two PCR products were generated using primer pairs consisting of a long, mutagenic primer and a shorter, non-mutagenic primer:

(5'-tccaaaactaaatctctgATAGAAGGTAGaacaagcgctgaacgac) with
(5'-CTTGATGTACTCTGTGAACGTGCTC); and

(5'-gtcgttcagcgctttgtTCTACCTTCTATcagagattagtttgga) with
(5'-ATGGAGTTCGTTAACAACAGTTC).

The products from these two reactions were used as templates for the splice-overlap extension PCR. A further PCR reaction was set up to add *Bam*HI and *Sal*I sites at either end of the activatable recLH_N/A gene and these sites were used for insertion into an Invitrogen gateway entry vector. The entry vector was then used, along with a gateway recombination site adapted pMAL c2x, in a LR clonase reaction to form pMAL c2x recLH_N/A. The pMAL c2x recLH_N/A was modified to incorporate a 6'HIS tag at the N-terminus of the MBP. This was achieved by the insertion of annealed oligonucleotides encoding the HIS tag into the *Nde*I site of pMAL.

The expression vector expressing LH_N/A was transformed into *E. coli* HMS174 or AD494(DE3) (Novagen). Cultures were grown in Terrific broth complex medium supplemented with ZnCl₂ (1 μM), ampicillin (100 μg/ml), 0.2% (w/v) glucose. Parameters for expression of all the constructs were initially determined in shake flask cultures before transferring into 8 L fermentor systems. Starter cultures were grown for 16 hours at 37°C, 220 rpm and used to inoculate 1 L in which growth was continued at 37°C, 250 rpm. At an OD_{600 nm} of 0.6 the temperature was reduced to 25°C for 30 minutes before induction with 1 mM IPTG. Induction was continued for 4 hours before the cells were harvested and stored at -70°C.

Typically 16 g of cell paste was suspended in 160 ml PBS and lysed by sonication (MSE Soniprep-150). The resulting lysate was clarified by centrifugation prior

loading onto a 25 ml amylose column and eluted with 10 mM maltose in PBS. The eluant contained approx. 50% pure fusion protein and was treated with Factor Xa (1 unit Factor Xa /100 µg fusion protein; 20 hours; 26°C) to remove the HISMBP and cleave the LC-H_N junction to activate the protein. After incubation the sample was
5 filtered (0.45 µm) and diluted two fold with water to give a 0.5 x PBS buffer composition. The cleaved, filtered and diluted recLH_N/A was processed through a Q Sepharose FF column (10 ml) and eluted with a step gradient of 80 mM NaCl containing HISMBP and 120 mM NaCl containing approx. 75% pure recLH_N/A. The addition of His tag to MBP overcame previous co-elution problems with LH_N/A and
10 MBP. As a final polishing step to ensure complete removal of the HISMBP, the 120 mM NaCl elution from the Q Sepharose column was passed through a Nickel charged 5 ml HisTrap column (Amersham). The flow through from the HisTrap column contained approx. 95% pure recLH_N/A (see the Figures in Sutton *et al.*, (2005), Prot. Express. Purif., 40, pp 31-41 for an illustration of the purification
15 scheme for LH_N/A).

Example 3 - Expression and purification of catalytically active recombinant LH_N/B

20 The methodology described below will purify catalytically active LH_N/B protease from *E. coli* transformed with the appropriate plasmid encoding the LH_N/B polypeptide. It should be noted that various sequences of suitable LH_N/B polypeptides have been described in PCT/GB97/02273, granted US 6 461617 and US patent application 10/241596, incorporated herein by reference.

25

Methods

The coding region for LH_N/B is inserted in-frame to the 3' of the gene encoding maltose binding protein (MBP) in the expression vector pMAL (New England Biolabs) to create pMAL- c2x-LH_N/B. In this construct, the expressed MBP and LH_N/B polypeptides are separated by a Factor Xa cleavage site, and the LC and H_N domains are separated by a peptide that is susceptible to cleavage with enterokinase. The expression clone is termed pMAL-c2X-synLH_N/B.

pMAL-c2X-synLH_N/B is transformed into *E. coli* HMS174 and cultured in Terrific broth complex medium in 8 L fermentor systems. Pre-induction bacterial growth is maintained at 37°C to an OD_{600 nm} of 5.0, at which stage expression of recMBP-LH_N/B is induced by addition of IPTG to 0.5 mM and a reduction in temperature to 30°C. After four hours at 30°C the bacteria are harvested by centrifugation and the resulting paste stored at -70°C.

The cell paste is resuspended in 20 mM Hepes pH 7.2, 125 mM NaCl, 1 µM ZnCl₂ and cell disruption achieved using an APV-Gaulin lab model 1000 homogeniser or a MSE Soniprep 150 sonicator. The resulting suspension is clarified by centrifugation prior to purification.

Following cell disruption, the MBP-fusion protein is captured either on an amylose affinity resin in 20 mM Hepes pH 7.2, 125 mM NaCl, 1 µM ZnCl₂, or on a Q-Sepharose FF anion-exchange resin in 50 mM Hepes pH 7.2, 1 µM ZnCl₂ with no salt. A single peak is eluted from the amylose resin in the same buffer plus 10 mM maltose and from the Q-Sepharose in 150-200 mM salt. Cleavage of the MBP-LH_N/B junction is completed in an 18 hours incubation step at 22°C with Factor Xa (NEB) at 1 U/50 µg fusion protein. A substrate (MBP-LH_N/B) concentration of at least 4 mg/ml is desirable for efficient cleavage to take place.

The cleaved protein is diluted with 20 mM Hepes to a buffer composition of 20 mM Hepes, 25 mM NaCl, 1 µM ZnCl₂, pH 7.2 and processed through a Q Sepharose column to separate the MBP from LH_N/B. The LH_N/B is eluted from the Q-Sepharose column with 120-170 mM salt. The linker between the light chain and H_N domain is then nicked by incubation with enterokinase at 1 U/100 µg of LH_N/B at 22°C for 16 hours. Finally, the enterokinase is separated from the nicked LH_N/B and other contaminating proteins on a Benzamidine Sepharose column, the enzyme preferentially binding to the resin over an incubation of 30 minutes at 4°C. Purified LH_N/B is stored at -20°C until required. See Figure 1 for an illustration of the purification scheme for recLH_N/B.

Example 4 - Expression and purification of catalytically active recombinant LH_N/C

The coding region for LH_N/C is inserted in-frame to the 3' of the gene encoding maltose binding protein (MBP) in the expression vector pMAL (New England Biolabs) to create pMAL- c2x- LH_N/C . In this construct the expressed MBP and LH_N/C polypeptides are separated by a Factor Xa cleavage site.

pMAL-c2x- LH_N/C is transformed into *E. coli* AD494 (DE3, IRL) and cultured in Terrific broth complex medium in 8 L fermentor systems. Pre-induction bacterial growth are maintained at 30°C to an OD600 nm of 8.0, at which stage expression of recMBP-c2x- LH_N/C is induced by addition of IPTG to 0.5 mM and a reduction in temperature of culture to 25°C. After 4 hours at 25°C the bacteria are harvested by centrifugation and the resulting paste stored at -70°C.

The cell paste is resuspended in 50 mM Hepes pH 7.2, 1 μ M $ZnCl_2$ at 1:6 (w/v) and cell disruption is achieved using an APV-Gaulin lab model 1000 homogeniser or a MSE Soniprep 150 sonicator. The resulting suspension is clarified by centrifugation prior to purification.

5

Following cell disruption and clarification, the MBP-fusion protein is separated on a Q-Sepharose Fast Flow anion-exchange resin in 50 mM Hepes pH 7.2, 1 μ M $ZnCl_2$ and eluted with the same buffer plus 100 mM NaCl. A double point cleavage is performed at the MBP- LH_N/C junction and the H_N -LC linker in a single incubation step with Factor Xa. The reaction is completed in a 16-hour incubation step at 22°C with Factor Xa (NEB) at 1 U/100 μ g fusion protein. The cleaved protein is diluted with 20 mM Hepes to a buffer composition of 20 mM Hepes, 25 mM NaCl, pH 7.2 and processed through a second Q-Sepharose column to separate the MBP from LH_N/C . Activated (disulphide-bonded cleaved linker) LH_N/C is eluted from the Q-Sepharose column by a salt gradient (20 mM Hepes, 500 mM NaCl, 1 μ M $ZnCl_2$, pH 7.2) in 120-170 mM salt. See Figure 2 for an illustration of the purification of

10

15

LH_N/C.

Example 5 - Production of a chemical conjugate of nociceptin and LH_N/A

5 *Materials*

C-terminally extended nociceptin peptide obtained from Sigma Genosys.
Conjugation chemicals obtained from Pierce.

Methods

- 10 In order to couple the nociceptin peptide via a C-terminal Cys, the peptide was first synthesised (by standard procedures, commercially obtainable) to include a Cys as the final C-terminal amino acid.

- 15 This peptide was then used as the second component in a sulphydryl based coupling reaction as described below (see also previous publications WO 99/17806 and WO 96/33273 and Duggan *et al.*, (2002), J. Biol. Chem. 277, 24846-34852 and Chaddock *et al.*, (2000), Infect Immun., 68, 2587-2593).

Sulphydryl based coupling reaction

- 20 Briefly, approximately two reactive leaving groups were introduced into LH_N/A (5 mg/ml in phosphate-buffered saline) by reaction with *N*-succinimidyl-3-(2-pyridyldithio)propionate (SPDP).

- 25 Derivatised material was isolated from excess SPDP by size exclusion chromatography. Reconstituted cysteine-tagged nociceptin ligand was mixed with the derivatised LH_N/A in a 4:1 molar ratio, and incubated at room temperature for 1 hour with gentle agitation in order to create a chemical conjugate through a reducible covalent disulphide bond. Initial fractionation of the conjugate mixture to remove unconjugated peptide was performed by size exclusion chromatography
30 (Superose-12, or Superdex G-200 depending on scale of conjugation).

Example 6 - Production of a chemical conjugate of nociceptin and LH_N/B

Materials

- 5 C-terminally extended nociceptin peptide obtained from Sigma Genosys.
Conjugation chemicals obtained from Pierce.

Methods

- 10 Lyophilised nociceptin was dissolved by the addition of water and dialysed into MES buffer (0.1 M MES, 0.1 M NaCl, pH 5.0). To this solution (at a concentration of about 0.3 mg/ml) was added PDPH (100 mg/ml in DMF) to a final concentration of 1 mg/ml. After mixing, solid EDAC was added to produce a final concentration of about 0.2 mg/ml. The reaction was allowed to proceed for at least 30 minutes at room temperature. Excess PDPH was then removed by desalting over a PD-10
15 column (Pharmacia) previously equilibrated with MES buffer.

- An amount of LH_N/B equivalent to half the weight of nociceptin used dissolved in triethanolamine buffer (0.02 M triethanolamine/HCl, 0.1 M sodium chloride, pH 7.8) at a concentration of about 1 mg/ml, was reacted with Traut's reagent (100 mM stock
20 solution in 1 M triethanolamine/HCl, pH 8.0) at a final concentration of 2 mM. After 1 hour, the LH_N/B was desalted into PBSE (phosphate buffered saline with 1 mM EDTA) using a PD-10 column (Pharmacia). The protein peak from the column eluate was concentrated using a Microcon 50 (Amicon) to a concentration of about 2 mg/ml.

25

- The derivatised nociceptin was subjected to a final concentration step resulting in a reduction in volume to less than 10% of the starting volume and then mixed with the derivatised LH_N/B overnight at room temperature. The products of the reaction were analysed by polyacrylamide gel electrophoresis in the presence of sodium dodecyl-
30 sulphate (SDS-PAGE).

The conjugate resulting from the above reaction was partially purified by size

exclusion chromatography over Bio-Gel P-100 (BioRad). The elution profile was followed by measuring the optical density at 280 nm and SDS-PAGE analysis of the fractions. This allowed the separation of conjugate from free nociceptin and by-products of the reaction.

5

Example 7 - Production of a chemical conjugate of nociceptin 1-11 and LH_N/B

Materials

C-terminally extended nociceptin 1-11 peptide obtained from Sigma Genosys.

10 Conjugation chemicals obtained from Pierce.

Methods

In order to couple the nociceptin 1-11 peptide via a C-terminal Cys, the peptide was first synthesised (by standard procedures, commercially obtainable) to include a

15 Cys as the final C-terminal amino acid.

This peptide was then used as the second component in a sulphydryl based coupling reaction as described in Example 5.

20 Example 8 - Production of a chemical conjugate of nociceptin N[[Y14]1-17] and LH_N/C

Materials

C-terminally extended nociceptin N[[Y14]1-17] peptide obtained from Sigma

25 Genosys.

Conjugation chemicals obtained from Pierce.

Methods

In order to couple the peptide via a C-terminal Cys, the peptide was first synthesised
30 (by standard procedures, commercially obtainable) to include a Cys as the final C-terminal amino acid.

This peptide was then used as the second component in a sulphydryl based coupling reaction as described in Example 5.

Example 9 - Recombinant production of a single polypeptide fusion of nociceptin-LH_N/A (SEQ ID15 and SEQ ID16)

The DNA sequence for the nociceptin-LH_N/A was designed by back translation of the LC/A, H_N/A, and nociceptin amino acid sequences. The complete ORF containing the nociceptin-LC/A-activation loop-H_N/A sequence was assembled within standard DNA sequence manipulation software (EditSeq). The activation loop between the LC/A cysteine and the H_N/A cysteine (CVRGIITSKTKSLDKGYNKALNDLC) was modified to incorporate a Factor Xa protease recognition site.

Restriction sites appropriate to facilitate cloning into the required expression vector (for example BamHI/Sall) were incorporated at the 5' and 3' ends respectively of the sequence maintaining the correct reading frame. The DNA sequence was screened (using software such as MapDraw, DNASTAR Inc.) for restriction enzyme cleavage sequences incorporated during the back translation. Any cleavage sequences that were found to be common to those required by the cloning system were removed manually from the proposed coding sequence ensuring common *E. coli* codon usage was maintained. *E. coli* codon usage was assessed by reference to software programs such as Graphical Codon Usage Analyser (Geneart), and the %GC content and codon usage ratio assessed by reference to published codon usage tables (for example GenBank Release 143, 13 September 2004).

This optimised DNA sequence containing the nociceptin-LC/A-activation loop-H_N/A open reading frame (ORF) was then commercially synthesized and provided in the pCR 4 vector.

The DNA encoding the nociceptin-LH_N/A fusion was isolated from pCR 4 and transferred into pMAL vector backbone to facilitate protein expression. The resultant pMAL: NO-LHN/A vector was transformed into competent *E. coli* BL21 and correct

transformants selected. A single colony of pMAL NO-LH_N/A was grown in Terrific broth complex medium supplemented with ZnCl₂ (1 mM), ampicillin (100 µg/ml), 0.2% (w/v) glucose. Expression of the insert was induced by the addition of IPTG (0.1 mM) and the culture maintained at 16°C for 16 hours. After this period of expression the bacteria were isolated by centrifugation and the cell pellet stored at -20°C until use.

10 g of *E. coli* BL21 cell paste was defrosted in a falcon tube containing 25 ml 50 mM HEPES, pH 7.2, 200 mM NaCl. The thawed cell paste was made up to 80 ml with 50 mM HEPES, pH 7.2, 200 mM NaCl and sonicated on ice 30 seconds on, 30 seconds off for 10 cycles at a power of 22 microns ensuring the sample remained cool. The lysed cells were centrifuged at 18 000 rpm, 4°C for 30 minutes. The supernatant was loaded onto a 0.1 M NiSO₄ charged chelating column (20-30 ml column is sufficient) and equilibrated with 50 mM HEPES, pH 7.2, 200 mM NaCl.

Using a step gradient of 10 and 40 mM imidazol, the non-specific bound protein was washed away and the fusion protein eluted with 100 mM imidazol. The eluted fusion protein was dialysed against 5 L of 50 mM HEPES, pH 7.2, 200 mM NaCl at 4°C overnight and the OD of the dialysed fusion protein measured. 1 unit of Factor Xa was added per 100 µg fusion protein and incubated at 25°C static overnight. The cleavage mixture was loaded onto a 0.1 M NiSO₄ charged Chelating column (20-30 ml column is sufficient) and equilibrated with 50 mM HEPES, pH 7.2, 200 mM NaCl.

Using a step gradient of 10 and 40 mM imidazol, the non-specific bound protein was washed away and the fusion protein eluted with 100 mM imidazol. The eluted fusion protein was dialysed against 5 L of 50 mM HEPES, pH 7.2, 200 mM NaCl at 4°C overnight and the fusion concentrated to about 2 mg/ml, aliquoted and stored at -20°C.

Figure 3 shows the SDS-PAGE analysis of expression and purification of N[1-17]-LH_N/A.

Example 10 – Recombinant production of a single polypeptide fusion of (nociceptin 1-11)-LH_N/B

- 5 The DNA sequence for the (nociceptin 1-11)-LH_N/B was designed by back translation of the LC/B, H_N/B, and nociceptin 1-11 amino acid sequences. The complete ORF containing the (nociceptin1-11)-LC/B-activation loop-H_N/B sequence was assembled within standard DNA sequence manipulation software (EditSeq). The activation loop between the LC/B cysteine and the H_N/B cysteine was modified
10 to incorporate a Factor Xa protease recognition site.

The recombinant fusion protein was then produced essentially as described in Example 9.

- 15 **Example 11 – Recombinant production of a single polypeptide fusion of (nociceptin N[[Y14]1-17]) - LH_N/C (SEQ ID25 and SEQ ID26)**

- The DNA sequence for the nociceptin N[[Y14]1-17] was designed by back translation of the LC/C, H_N/C, and nociceptin N[[Y14]1-17] amino acid sequences. The
20 complete ORF containing the (nociceptin N[[Y14]1-17])-LC/C-activation loop-H_N/C sequence was assembled within standard DNA sequence manipulation software (EditSeq). The activation loop between the LC/C cysteine and the H_N/C cysteine was modified to incorporate a Factor Xa protease recognition site.

- 25 The recombinant fusion protein was then produced essentially as described in Example 9.

- Example 12 – Recombinant production of a single polypeptide fusion of LH_N/C-**
30 **(nociceptin 1-11) (SEQ ID23 and SEQ ID24)**

The DNA sequence for the LH_N/C-(nociceptin 1-11) was designed by back

translation of the LC/C, H_N/C and nociceptin 1-11 amino acid sequences. The complete ORF (SEQ ID23) containing the LC/C-activation loop-H_N/C-flexible spacer-(nociceptin 1-11) was assembled within standard DNA sequence manipulation software (EditSeq).

5

The recombinant fusion protein (SEQ ID24) was then produced essentially as described in Example 9.

10 **Example 13 - Production of a conjugate for delivery of DNA encoding LC/C into a cell**

The construction of a nociceptin-H_N-[LC/C] conjugate is described below, where [LC/C] represents the polylysine condensed DNA encoding the light chain of botulinum neurotoxin type C.

15

Materials

SPDP is from Pierce Chemical Co.

Additional reagents are obtained from Sigma Ltd.

20 *Methods*

Using a plasmid containing the gene encoding LC/C under the control of a CMV (immediate early) promoter, condensation of DNA was achieved using SPDP-derivatised polylysine to a ratio of 2 DNA to 1 polylysine. Conjugates were then prepared by mixing condensed DNA (0.4 mg/ml) with H_N-nociceptin (100 µg/ml) for
25 16 h at 25°C. The SPDP-derivatised polylysine and the free -SH group present on the H_N domain combine to facilitate covalent attachment of the DNA and protein.

30

Example 14 - Production of a conjugate for delivery of DNA encoding LC/B into a cell

The construction of a (nociceptin 1-11)-H_N-[LC/B] conjugate is described below, where [LC/B] represents the polylysine condensed DNA encoding the light chain of

botulinum neurotoxin type B.

Materials

SPDP is from Pierce Chemical Co.

5 Additional reagents are obtained from Sigma Ltd.

Methods

Using a plasmid containing the gene encoding LC/B under the control of a CMV (immediate early) promoter, condensation of DNA was achieved using SPDP-derivatised polylysine to a ratio of 2 DNA to 1 polylysine. Conjugates were then prepared by mixing condensed DNA (0.4 mg/ml) with H_N-(nociceptin 1-11) (100 µg/ml) for 16 h at 25°C. The SPDP-derivatised polylysine and the free -SH group present on the H_N domain combine to facilitate covalent attachment of the DNA and protein.

15

Example 15 – Assessment of the activity of nociceptin-LH_N/A in substance P releasing neuronal cells

Using methodology described in Duggan *et al.*, (2002, J. Biol. Chem., 277, 34846-34852), the activity of nociceptin-LH_N/A in substance P releasing neuronal cells was assessed.

Nociceptin-LH_N/A fusion protein was applied to 2-week old dorsal root ganglia neuronal cultures, and incubated at 37°C for 16 hours. Following the incubation, the media was removed and the ability of the cells to undergo stimulated release of substance P (SP) was assessed.

The release of SP from the neuronal cells incubated with the nociceptin-LH_N/A fusion protein was assayed in comparison to (i) LH_N/A-only treated cells and (ii) cells treated with media alone. This allowed the % inhibition of substance P from the eDRG to be calculated. The ability of the nociceptin-LH_N/A fusion protein to inhibit SP release (relative to cells treated with media alone) was reported in Table 1. The

data represent the mean of 3 determinations:

Table 1

Test Material (μM)	nociceptin-LH _N /A fusion protein	LH _N /A-only
	% Inhibition	% Inhibition
1.0	47.3	25.6
0.1	13.8	-11.5

5

Example 16 - Confirmation of ORL₁ receptor activation by measuring forskolin-stimulated cAMP production

Confirmation that a given TM is acting via the ORL₁ receptor is provided by the
 10 following test, in which the TMs ability to inhibit forskolin-stimulated cAMP production is assessed.

Materials

[³H]adenine and [¹⁴C]cAMP are obtained from GE Healthcare

15

Methods

The test is conducted essentially as described previously by Meunier *et al.* [Isolation and structure of the endogenous agonist of opioid receptor-like ORL₁ receptor. Nature 377: 532-535, 1995] in intact transfected-CHO cells plated on 24-well plastic
 20 plates.

To the cells is added [3H]adenine (1.0 μCi) in 0.4 ml of culture medium. The cells remain at 37°C for 2 h to allow the adenine to incorporate into the intracellular ATP pool. After 2 h, the cells are washed once with incubation buffer containing: 130 mM
 25 NaCl, 4.8 mM KCl, 1.2 mM KH₂PO₄, 1.3 mM CaCl₂, 1.2 mM MgSO₄, 10 mM glucose, 1 mg/ml bovine serum albumin and 25 mM HEPES, pH 7.4, and replaced with buffer containing forskolin (10 μM) and isobutylmethylxanthine (50 μM) with or without the

TM of interest. After 10 min., the medium is aspirated and replaced with 0.5 ml, 0.2 M HCl. Approximately 1000 cpm of [^{14}C]cAMP is added to each well and used as an internal standard. The contents of the wells are then transferred to columns of 0.65 g dry alumina powder. The columns are eluted with 4 ml of 5 mM HCl, 0.5 ml of 0.1 M ammonium acetate, then two additional millilitres of ammonium acetate. The final eluate is collected into scintillation vials and counted for ^{14}C and tritium. Amounts collected are corrected for recovery of [^{14}C]cAMP. TMs that are agonists at the ORL₁ receptor cause a reduction in the level of cAMP produced in response to forskolin.

Example 17 - Confirmation of ORL₁ receptor activation using a GTP γ S binding functional assay

Confirmation that a given TM is acting via the ORL₁ receptor is also provided by the following test, a GTP γ S binding functional assay.

Materials

[^{35}S]GTP γ S is obtained from GE Healthcare

Wheatgerm agglutinin-coated (SPA) beads are obtained from GE Healthcare

Methods

This assay is carried out essentially as described by Traynor and Nahorski [Modulation by μ -opioid agonists of guanosine-5'-O-(3-[^{35}S]thio)triphosphate binding to membranes from human neuroblastoma SH-SY5Y cells. Mol. Pharmacol. 47: 848-854, 1995].

Cells are scraped from tissue culture dishes into 20 mM HEPES, 1 mM ethylenediaminetetraacetic acid, then centrifuged at $500 \times g$ for 10 min. Cells are resuspended in this buffer and homogenized with a Polytron Homogenizer.

The homogenate is centrifuged at $27,000 \times g$ for 15 min., and the pellet resuspended in buffer A, containing: 20 mM HEPES, 10 mM MgCl₂, 100 mM NaCl,

pH 7.4. The suspension is recentrifuged at $20,000 \times g$ and suspended once more in buffer A. For the binding assay, membranes (8-15 μg protein) are incubated with [^{35}S]GTP S (50 pM), GDP (10 μM), with and without the TM of interest, in a total volume of 1.0 ml, for 60 min. at 25°C. Samples are filtered over glass fibre filters
5 and counted as described for the binding assays.

Example 18 - Preparation of a LC/A and H_N/A backbone clones

The following procedure creates the LC and H_N fragments for use as the component
10 backbone for multidomain fusion expression. This example is based on preparation of a serotype A based clone (SEQ ID27 and SEQ ID28), though the procedures and methods are equally applicable to the other serotypes [illustrated by the sequence listing for serotype B (SEQ ID29 and SEQ ID30) and serotype C (SEQ ID31 and SEQ ID32)].

15

Preparation of cloning and expression vectors

pCR 4 (Invitrogen) is the chosen standard cloning vector, selected due to the lack of restriction sequences within the vector and adjacent sequencing primer sites for easy construct confirmation. The expression vector is based on the pMAL (NEB)
20 expression vector, which has the desired restriction sequences within the multiple cloning site in the correct orientation for construct insertion (*Bam*HI-*Sal*I-*Pst*II-*Hind*III). A fragment of the expression vector has been removed to create a non-mobilisable plasmid and a variety of different fusion tags have been inserted to increase purification options.

25

Preparation of protease (e.g. LC/A) insert

The LC/A (SEQ ID27) is created by one of two ways:

The DNA sequence is designed by back translation of the LC/A amino acid sequence [obtained from freely available database sources such as GenBank
30 (accession number P10845) or Swissprot (accession locus BXA1_CLOBO) using one of a variety of reverse translation software tools (for example EditSeq best *E. coli*.reverse translation.(DNASTAR Inc.), or Backtranslation.tool v2.0 (Entelechon)].

*Bam*HI/*Sa*II recognition sequences are incorporated at the 5' and 3' ends respectively of the sequence, maintaining the correct reading frame. The DNA sequence is screened (using software such as MapDraw, DNASTAR Inc.) for restriction enzyme cleavage sequences incorporated during the back translation.

5 Any cleavage sequences that are found to be common to those required by the cloning system are removed manually from the proposed coding sequence ensuring common *E. coli* codon usage is maintained. *E. coli* codon usage is assessed by reference to software programs such as Graphical Codon Usage Analyser (Geneart), and the %GC content and codon usage ratio assessed by reference to
10 published codon usage tables (for example GenBank Release 143, 13 September 2004). This optimised DNA sequence containing the LC/A open reading frame (ORF) is then commercially synthesized (for example by Entelechon, Geneart or Sigma-Genosys) and is provided in the pCR 4 vector.

15 The alternative method is to use PCR amplification from an existing DNA sequence with *Bam*HI and *Sa*II restriction enzyme sequences incorporated into the 5' and 3' PCR primers respectively. Complementary oligonucleotide primers are chemically synthesised by a supplier (for example MWG or Sigma-Genosys), so that each pair has the ability to hybridize to the opposite strands (3' ends pointing "towards" each
20 other) flanking the stretch of *Clostridium* target DNA, one oligonucleotide for each of the two DNA strands. To generate a PCR product the pair of short oligonucleotide primers specific for the *Clostridium* DNA sequence are mixed with the *Clostridium* DNA template and other reaction components and placed in a machine (the 'PCR machine') that can change the incubation temperature of the reaction tube
25 automatically, cycling between approximately 94°C (for denaturation), 55°C (for oligonucleotide annealing), and 72°C (for synthesis). Other reagents required for amplification of a PCR product include a DNA polymerase (such as *Taq* or *Pfu* polymerase), each of the four nucleotide dNTP building blocks of DNA in equimolar amounts (50-200 µM) and a buffer appropriate for the enzyme optimised for Mg²⁺
30 concentration (0.5-5 mM).

The amplification product is cloned into pCR 4 using either, TOPO TA cloning for *Taq* PCR products or Zero Blunt TOPO cloning for *Pfu* PCR products (both kits commercially available from Invitrogen). The resultant clone is checked by sequencing. Any additional restriction sequences which are not compatible with the cloning system are then removed using site directed mutagenesis [for example, using Quickchange (Stratagene Inc.)].

Preparation of translocation (e.g. H_N) insert

The H_N/A (SEQ ID28) is created by one of two ways:

- 10 The DNA sequence is designed by back translation of the H_N/A amino acid sequence [obtained from freely available database sources such as GenBank (accession number P10845) or Swissprot (accession locus BXA1_CLOBO)] using one of a variety of reverse translation software tools [for example EditSeq best *E. coli* reverse translation (DNASTAR Inc.), or Backtranslation tool v2.0 (Entelechon)].
- 15 A *Pst*I restriction sequence added to the N-terminus and *Xba*I-stop codon-*Hind*III to the C-terminus ensuring the correct reading frame is maintained. The DNA sequence is screened (using software such as MapDraw, DNASTAR Inc.) for restriction enzyme cleavage sequences incorporated during the back translation. Any sequences that are found to be common to those required by the cloning
- 20 system are removed manually from the proposed coding sequence ensuring common *E. coli* codon usage is maintained. *E. coli* codon usage is assessed by reference to software programs such as Graphical Codon Usage Analyser (Geneart), and the %GC content and codon usage ratio assessed by reference to published codon usage tables (for example GenBank Release 143, 13 September
- 25 2004). This optimised DNA sequence is then commercially synthesized (for example by Entelechon, Geneart or Sigma-Genosys) and is provided in the pCR 4 vector.

The alternative method is to use PCR amplification from an existing DNA sequence with *Pst*I and *Xba*I-stop codon-*Hind*III restriction enzyme sequences incorporated into the 5' and 3' PCR primers respectively. The PCR amplification is performed as described above. The PCR product is inserted into pCR 4 vector and checked by

sequencing. Any additional restriction sequences which are not compatible with the cloning system are then removed using site directed mutagenesis [for example using Quickchange (Stratagene Inc.)].

5 Example 19 – Preparation of a LC/A-nociceptin-H_N/A fusion protein (nociceptin is N-terminal of the H_N-chain)

Preparation of linker-nociceptin-spacer insert

The LC-H_N linker can be designed from first principle, using the existing sequence
10 information for the linker as the template. For example, the serotype A linker (in this case defined as the inter-domain polypeptide region that exists between the cysteines of the disulphide bridge between LC and H_N) is 23 amino acids long and has the sequence VRGIITSKTKSLDKGYNKALNDL. Within this sequence, it is understood that proteolytic activation in nature leads to an H_N domain that has an N-
15 terminus of the sequence ALNDL. This sequence information is freely available from available database sources such as GenBank (accession number P10845) or Swissprot (accession locus BXA1_CLOBO). Into this linker a Factor Xa site, nociceptin and spacer are incorporated; and using one of a variety of reverse translation software tools [for example EditSeq best *E. coli* reverse translation
20 (DNASTAR Inc.), or Backtranslation tool v2.0 (Entelechon)], the DNA sequence encoding the linker-ligand-spacer region is determined. Restriction sites are then incorporated into the DNA sequence and can be arranged as *Bam*HI-*Sal*I-linker-protease site-nociceptin-*Nhe*I-spacer-*Spe*I-*Pst*I-*Xba*I-stop codon-*Hind*III (SEQ ID33). It is important to ensure the correct reading frame is maintained for the spacer,
25 nociceptin and restriction sequences and that the *Xba*I sequence is not preceded by the bases, TC, which would result on DAM methylation. The DNA sequence is screened for restriction sequence incorporation, and any additional sequences are removed manually from the remaining sequence ensuring common *E. coli* codon usage is maintained. *E. coli* codon usage is assessed by reference to software
30 programs such as Graphical Codon Usage Analyser (Geneart), and the %GC content and codon usage ratio assessed by reference to published codon usage tables (for example, GenBank Release-143, 13 September 2004). This optimised

DNA sequence is then commercially synthesized (for example by Entelechon, Geneart or Sigma-Genosys) and is provided in the pCR 4 vector.

Preparation of the LC/A-nociceptin-H_N/A fusion

5 In order to create the LC-linker-nociceptin-spacer-H_N construct (SEQ ID39), the pCR 4 vector encoding the linker (SEQ ID33) is cleaved with *Bam*HI + *Sa*II restriction enzymes. This cleaved vector then serves as the recipient vector for insertion and ligation of the LC/A DNA (SEQ ID27) cleaved with *Bam*HI + *Sa*II. The resulting plasmid DNA is then cleaved with *Pst*I + *Xba*I restriction enzymes and serves as the
10 recipient vector for the insertion and ligation of the H_N/A DNA (SEQ ID28) cleaved with *Pst*I + *Xba*I. The final construct contains the LC-linker-nociceptin-spacer-H_N ORF (SEQ ID39) for transfer into expression vectors for expression to result in a fusion protein of the sequence illustrated in SEQ ID40.

15 **Example 20 – Preparation of a nociceptin-LC/A-H_N/A fusion protein (nociceptin is N-terminal of the LC-chain)**

The LC/A-H_N/A backbone is constructed as described in Example 19 using the synthesised A serotype linker with the addition of a Factor Xa site for activation,
20 arranged as *Bam*HI-*Sa*II-linker-protease site-linker-*Pst*I-*Xba*I-stop codon-*Hind*III (SEQ ID34). The LC/A-H_N/A backbone and the synthesised N-terminal presentation nociceptin insert (SEQ ID35) are cleaved with *Bam*HI + *Hind*III restriction enzymes, gel purified and ligated together to create a nociceptin-spacer-LC-linker-H_N. The ORF (SEQ ID41) is then cut out using restriction enzymes *Ava*I + *Xba*I for transfer
25 into expression vectors for expression to result in a fusion protein of the sequence illustrated in SEQ ID42.

Example 21 – Preparation of a LC/C-nociceptin-H_N/C fusion protein

30 Following the methods used in Examples 1 and 2, the LC/C (SEQ ID31) and H_N/C (SEQ ID32) are created and inserted into the C serotype linker arranged as *Bam*HI-*Sa*II-linker-protease site-nociceptin-*Nhe*I-spacer-*Spe*I-*Pst*I-*Xba*I-stop codon-*Hind*III

(SEQ ID36). The final construct contains the LC-linker-nociceptin-spacer-H_N ORF (SEQ ID43) for expression as a protein of the sequence illustrated in SEQ ID44.

Example 22 - Preparation of a LC/C-nociceptin-H_N/C fusion protein with a serotype A activation sequence

Following the methods used in Examples 1 and 2, the LC/C (SEQ ID31) and H_N/C (SEQ ID32) are created and inserted into the A serotype linker arranged as *Bam*HI-*Sa*II-linker-protease site-nociceptin-*Nhe*I-spacer-*Spe*I-*Pst*II-*Xba*I-stop codon-*Hind*III (SEQ ID33). The final construct contains the LC-linker-nociceptin-spacer-H_N ORF (SEQ ID45) for expression as a protein of the sequence illustrated in SEQ ID46.

Example 23 - Preparation of a LC/A-met enkephalin-H_N/A fusion protein

Due to the small, five-amino acid, size of the met-enkephalin ligand the LC/A-met enkephalin-H_N/A fusion is created by site directed mutagenesis [for example using Quickchange (Stratagene Inc.)] using the LC/A-nociceptin-H_N/A fusion (SEQ ID39) as a template. Oligonucleotides are designed encoding the YGGFM met-enkephalin peptide, ensuring standard *E.coli* codon usage is maintained and no additional restriction sites are incorporated, flanked by sequences complimentary to the linker region of the LC/A-nociceptin-H_N/A fusion (SEQ ID39) either side on the nociceptin section. The SDM product is checked by sequencing and the final construct containing the LC-linker-met enkephalin-spacer-H_N ORF (SEQ ID47) for expression as a protein of the sequence illustrated in SEQ ID48.

Example 24 - Preparation of a LC/A-β endorphin-H_N/A fusion protein

Following the methods used in Examples 1 and 2, the LC/A (SEQ ID27) and H_N/A (SEQ ID28) are created and inserted into the A serotype β endorphin linker arranged as *Bam*HI-*Sa*II-linker-protease site-β endorphin-*Nhe*I-spacer-*Spe*I-*Pst*II-*Xba*I-stop codon-*Hind*III (SEQ ID37). The final construct contains the LC-linker-β endorphin-

spacer-H_N ORF (SEQ ID49) for expression as a protein of the sequence illustrated in SEQ ID50.

Example 25 - Preparation of a LC/A-nociceptin variant-H_N/A fusion protein

5

Following the methods used in Examples 1 and 2, the LC/A (SEQ ID27) and H_N/A (SEQ ID28) are created and inserted into the A serotype nociceptin variant linker arranged as *Bam*HI-*Sa*II-linker-protease site-nociceptin variant-*Nhe*I-spacer-*Spe*I-*Pst*I-*Xba*I-stop codon-*Hind*III (SEQ ID38). The final construct contains the LC-
10 linker-nociceptin variant-spacer-H_N ORF (SEQ ID51) for expression as a protein of the sequence illustrated in SEQ ID52.

Example 26 – Purification method for LC/A-nociceptin-H_N/A fusion protein

15 Defrost falcon tube containing 25 ml 50 mM HEPES pH 7.2, 200 mM NaCl and approximately 10 g of *E. coli* BL21 cell paste. Make the thawed cell paste up to 80 ml with 50 mM HEPES pH 7.2, 200 mM NaCl and sonicate on ice 30 seconds on, 30 seconds off for 10 cycles at a power of 22 microns ensuring the sample remains cool. Spin the lysed cells at 18 000 rpm, 4°C for 30 minutes. Load the supernatant
20 onto a 0.1 M NiSO₄ charged Chelating column (20-30 ml column is sufficient) equilibrated with 50 mM HEPES pH 7.2, 200 mM NaCl. Using a step gradient of 10 and 40 mM imidazol, wash away the non-specific bound protein and elute the fusion protein with 100 mM imidazol. Dialyse the eluted fusion protein against 5 L of 50 mM HEPES pH 7.2, 200 mM NaCl at 4°C overnight and measure the OD of the
25 dialysed fusion protein. Add 1 unit of factor Xa per 100 µg fusion protein and Incubate at 25°C static overnight. Load onto a 0.1 M NiSO₄ charged Chelating column (20-30 ml column is sufficient) equilibrated with 50 mM HEPES pH 7.2, 200 mM NaCl. Wash column to baseline with 50 mM HEPES pH 7.2, 200 mM NaCl. Using a step gradient of 10 and 40 mM imidazol, wash away the non-specific bound
30 protein and elute the fusion protein with 100 mM imidazol. Dialyse the eluted fusion protein against 5 L of 50 mM HEPES pH 7.2, 200 mM NaCl at 4°C overnight and

concentrate the fusion to about 2 mg/ml, aliquot sample and freeze at -20°C. Test purified protein using OD, BCA, purity analysis and SNAP-25 assessments.

Example 27 – Preparation of a LC/A-nociceptin-H_N/A fusion protein (nociceptin is N-terminal of the H_N-chain)

The linker-nociceptin-spacer insert is prepared as described in Example 19.

Preparation of the LC/A-nociceptin-H_N/A fusion

In order to create the LC-linker-nociceptin-spacer-H_N construct (SEQ ID39), the pCR 4 vector encoding the linker (SEQ ID33) is cleaved with *Bam*HI + *Sal*I restriction enzymes. This cleaved vector then serves as the recipient for insertion and ligation of the LC/A DNA (SEQ ID27) also cleaved with *Bam*HI + *Sal*I. The resulting plasmid DNA is then cleaved with *Bam*HI + *Hind*III restriction enzymes and the LC/A-linker fragment inserted into a similarly cleaved vector containing a unique multiple cloning site for *Bam*HI, *Sal*I, *Pst*I, and *Hind*III such as the pMAL vector (NEB). The H_N/A DNA (SEQ ID28) is then cleaved with *Pst*I + *Hind*III restriction enzymes and inserted into the similarly cleaved pMAL-LC/A-linker construct. The final construct contains the LC-linker-nociceptin-spacer-H_N ORF (SEQ ID39) for expression as a protein of the sequence illustrated in SEQ ID40.

Example 28 – Preparation of a nociceptin-LC/A-H_N/A fusion protein (nociceptin is N-terminal of the LC-chain)

In order to create the nociceptin-spacer-LC/A-H_N/A construct, an A serotype linker with the addition of a Factor Xa site for activation, arranged as *Bam*HI-*Sal*I-linker-protease site-linker-*Pst*I-*Xba*I-stop codon-*Hind*III (SEQ ID34) is synthesised as described in Example 27. The pCR 4 vector encoding the linker is cleaved with *Bam*HI + *Sal*I restriction enzymes. This cleaved vector then serves as the recipient for insertion and ligation of the LC/A DNA (SEQ ID27) also cleaved with *Bam*HI + *Sal*I. The resulting plasmid DNA is then cleaved with *Bam*HI + *Hind*III restriction

enzymes and the LC/A-linker fragment inserted into a similarly cleaved vector containing the synthesised N-terminal presentation nociceptin insert (SEQ ID35). This construct is then cleaved with *Ava*I + *Hind*III and inserted into an expression vector such as the pMAL plasmid (NEB). The H_N/A DNA (SEQ ID28) is then cleaved
5 with *Pst*I + *Hind*III restriction enzymes and inserted into the similarly cleaved pMAL-nociceptin-LC/A-linker construct. The final construct contains the nociceptin-spacer-LC/A-H_N/A ORF (SEQ ID63) for expression as a protein of the sequence illustrated in SEQ ID64.

10 **Example 29 - Preparation and purification of an LC/A-nociceptin-H_N/A fusion protein family with variable spacer length**

Using the same strategy as employed in Example 19, a range of DNA linkers were prepared that encoded nociceptin and variable spacer content. Using one of a
15 variety of reverse translation software tools [for example EditSeq best *E. coli* reverse translation (DNASTAR Inc.), or Backtranslation tool v2.0 (Entelechon)], the DNA sequence encoding the linker-ligand-spacer region is determined. Restriction sites are then incorporated into the DNA sequence and can be arranged as *Bam*HI-*Sal*I-linker-protease site-nociceptin-*Nhe*I-spacer-*Spe*I-*Pst*I-*Xba*I-stop codon-*Hind*III (SEQ
20 ID65 to SEQ ID69). It is important to ensure the correct reading frame is maintained for the spacer, nociceptin and restriction sequences and that the *Xba*I sequence is not preceded by the bases, TC which would result on DAM methylation. The DNA sequence is screened for restriction sequence incorporation and any additional
25 sequences are removed manually from the remaining sequence ensuring common *E. coli* codon usage is maintained. *E. coli* codon usage is assessed by reference to software programs such as Graphical Codon Usage Analyser (Geneart), and the %GC content and codon usage ratio assessed by reference to published codon usage tables (for example GenBank Release 143, 13 September 2004). This
30 optimised DNA sequence is then commercially synthesized (for example by Entelechon, Geneart or Sigma-Genosys) and is provided in the pCR 4 vector.

The spacers that were created included:

Table 2

<u>Code</u>	<u>Protein sequence of the linker</u>	<u>SEQ ID of the linker DNA</u>
GS10	ALAGGGGSALVLQ	53
GS15	ALAGGGGSGGGGSALVLQ	54
GS25	ALAGGGGSGGGGSGGGGSGGGGSALVLQ	55
GS30	ALAGGGGSGGGGSGGGGSGGGGSGGGGSALVLQ	56
HX27	ALAAEAAAKEAAAKEAAKAGGGGSALVLQ	57

By way of example, in order to create the LC/A-CPN(GS15)-H_N/A fusion construct (SEQ ID70), the pCR 4 vector encoding the linker (SEQ ID66) is cleaved with *Bam*HI + *Sa*II restriction enzymes. This cleaved vector then serves as the recipient vector for insertion and ligation of the LC/A DNA (SEQ ID27) also cleaved with *Bam*HI + *Sa*II. The resulting plasmid DNA is then cleaved with *Bam*HI + *Hind*III restriction enzymes and the LC/A-linker fragment inserted into a similarly cleaved vector containing a unique multiple cloning site for *Bam*HI, *Sa*II, *Pst*I, and *Hind*III such as the pMAL vector (NEB). The H_N/A DNA (SEQ ID28) is then cleaved with *Pst*I + *Hind*III restriction enzymes and inserted into the similarly cleaved pMAL-LC/A-linker construct. The final construct contains the LC/A-CPN(GS15)-H_N/A ORF (SEQ ID70) for expression as a protein of the sequence illustrated in SEQ ID71.

15

As a further example, to create the LC/A-CPN(GS25)-H_N/A fusion construct (SEQ ID72), the pCR 4 vector encoding the linker (SEQ ID67) is cleaved with *Bam*HI + *Sa*II restriction enzymes. This cleaved vector then serves as the recipient vector for insertion and ligation of the LC/A DNA (SEQ ID27) cleaved with *Bam*HI + *Sa*II. The resulting plasmid DNA is then cleaved with *Bam*HI + *Hind*III restriction enzymes and the LC/A-linker fragment inserted into a similarly cleaved vector containing a unique multiple cloning site for *Bam*HI, *Sa*II, *Pst*I, and *Hind*III such as the pMAL vector (NEB). The H_N/A DNA (SEQ ID28) is then cleaved with *Pst*I + *Hind*III restriction enzymes and inserted into the similarly cleaved pMAL-LC/A-linker construct. The

20

final construct contains the LC/A-CPN(GS25)-H_N/A ORF (SEQ ID72) for expression as a protein of the sequence illustrated in SEQ ID73.

5 Variants of the LC/A-CPN-H_N/A fusion consisting of GS10, GS30 and HX27 are similarly created. Using the purification methodology described in Example 26, fusion protein is purified from *E. coli* cell paste. Figure 12 illustrates the purified product obtained in the case of LC/A-CPN(GS10)-H_N/A, LC/A-CPN(GS15)-H_N/A, LC/A-CPN(GS25)-H_N/A, LC/A-CPN(GS30)-H_N/A and LC/A-CPN(HX27)-H_N/A.

10 **Example 30 - Assessment of *in vitro* efficacy of an LC/A-nociceptin-H_N/A fusion**

Fusion protein prepared according to Examples 2 and 9 was assessed in the eDRG neuronal cell model.

15

Assays for the inhibition of substance P release and cleavage of SNAP-25 have been previously reported (Duggan *et al.*, 2002, *J. Biol. Chem.*, 277, 34846-34852). Briefly, dorsal root ganglia neurons are harvested from 15-day-old fetal Sprague-Dawley rats and dissociated cells plated onto 24-well plates coated with Matrigel at a density of 1 x 10⁶ cells/well. One day post-plating the cells are treated with 10 μM cytosine β-D-arabinofuranoside for 48 h. Cells are maintained in Dulbecco's minimal essential medium supplemented with 5% heat-inactivated fetal bovine serum, 5 mM L-glutamine, 0.6% D-glucose, 2% B27 supplement, and 100 ng/ml 2.5S mouse nerve growth factor. Cultures are maintained for 2 weeks at 37°C in 95% air/5%
20 CO₂ before addition of test materials.

25

Release of substance P from eDRG is assessed by enzyme-linked immunosorbent assay. Briefly, eDRG cells are washed twice with low potassium-balanced salt solution (BSS: 5 mM KCl, 137 mM NaCl, 1.2 mM MgCl₂, 5 mM glucose, 0.44 mM
30 KH₂PO₄, 20 mM HEPES, pH 7.4, 2 mM CaCl₂). Basal samples are obtained by incubating each well for 5 min. with 1 ml of low potassium BSS. After removal of this

buffer, the cells are stimulated to release by incubation with 1 ml of high potassium buffer (BSS as above with modification to include 100 mM KCl isotonicity balanced with NaCl) for 5 min. All samples are removed to tubes on ice prior to assay of substance P. Total cell lysates are prepared by addition of 250 μ l of 2 M acetic acid/0.1% trifluoroacetic acid to lyse the cells, centrifugal evaporation, and resuspension in 500 μ l of assay buffer. Diluted samples are assessed for substance P content. Substance P immunoreactivity is measured using Substance P Enzyme Immunoassay Kits (Cayman Chemical Company or R&D Systems) according to manufacturers' instructions. Substance P is expressed in pg/ml relative to a standard substance P curve run in parallel.

SDS-PAGE and Western blot analysis were performed using standard protocols (Novex). SNAP-25 proteins were resolved on a 12% Tris/glycine polyacrylamide gel (Novex) and subsequently transferred to nitrocellulose membrane. The membranes were probed with a monoclonal antibody (SMI-81) that recognises cleaved and intact SNAP-25. Specific binding was visualised using peroxidase-conjugated secondary antibodies and a chemiluminescent detection system. Cleavage of SNAP-25 was quantified by scanning densitometry (Molecular Dynamics Personal SI, ImageQuant data analysis software). Percent SNAP-25 cleavage was calculated according to the formula: $(\text{Cleaved SNAP-25}/(\text{Cleaved} + \text{Intact SNAP-25})) \times 100$.

Following exposure of eDRG neurons to an LC/A-nociceptin-H_N/A fusion (termed CPN-A), both inhibition of substance P release and cleavage of SNAP-25 are observed (Figure 13). After 24 h exposure to the fusion, 50% of maximal SNAP-25 cleavage is achieved by a fusion concentration of 6.3 ± 2.5 nM.

The effect of the fusion is also assessed at defined time points following a 16 h exposure of eDRG to CPN-A. Figure 14 illustrates the prolonged duration of action of the CPN-A fusion protein, with measurable activity still being observed at 28 days post exposure.

Example 31 - Assessment of *in vitro* efficacy of an LC/A-nociceptin variant-H_N/A fusion

Fusion protein prepared according to Examples 8 and 9 was assessed in the eDRG neuronal cell mode using the method described in Example 30.

Following exposure of eDRG neurons to an LC/A-nociceptin variant-H_N/A fusion (termed CPNv-A), both inhibition of substance P release and cleavage of SNAP-25 are observed. After 24 h exposure to the fusion, 50% of maximal SNAP-25 cleavage is achieved by a fusion concentration of 1.4 ± 0.4 nM (Figure 15).

The effect of the fusion is also assessed at defined time points following a 16 h exposure of eDRG to CPN-A. Figure 16 illustrates the prolonged duration of action of the CPN-A fusion protein, with measurable activity still being observed at 24 days post exposure.

The binding capability of the CPNv-A fusion protein is also assessed in comparison to the CPN-A fusion. Figure 17 illustrates the results of a competition experiment to determine binding efficacy at the ORL-1 receptor. CPNv-A is demonstrated to displace [3H]-nociceptin, thereby confirming that access to the receptor is possible with the ligand in the central presentation format.

Example 32 - Preparation of an LC/A-nociceptin variant-H_N/A fusion protein that is activated by treatment with Enterokinase

Following the methods used in Examples 1 and 2, the LC/A (SEQ ID27) and H_N/A (SEQ ID28) are created and inserted into the A serotype nociceptin variant linker arranged as *Bam*HI-SalI-linker-enterokinase protease site-nociceptin variant-*Nhe*I-spacer-*Spe*I-*Pst*II-*Xba*I-stop codon-*Hind*III (SEQ ID74). The final construct contains the LC-linker-nociceptin variant-spacer-H_N ORF sequences (SEQ ID75) for expression as a protein of the sequence illustrated in SEQ ID76. The fusion protein is termed CPNv(Ek)-A. Figure 18 illustrates the purification of CPNv(Ek)-A from *E.*

coli following the methods used in Example 26 but using Enterokinase for activation at 0.00064 µg per 100 µg of fusion protein.

Example 33 - Assessment of *in vitro* efficacy of an LC/A-nociceptin variant-H_N/A fusion that has been activated by treatment with enterokinase

The CPNv(Ek)-A prepared in Example 32 is obtained in a purified form and applied to the eDRG cell model to assess cleavage of SNAP-25 (using methodology from Example 30). Figure 19 illustrates the cleavage of SNAP-25 following 24 h exposure of eDRG to CPNv(Ek)-A. The efficiency of cleavage is observed to be similar to that achieved with the Factor Xa-cleaved material, as recorded in Example 31.

Example 34 - Preparation of an LC/C-nociceptin variant-H_N/C fusion protein with a Factor Xa activation linker derived from serotype A

Following the methods used in Example 21, the LC/C (SEQ ID31) and H_N/C (SEQ ID32) are created and inserted into the A serotype nociceptin variant linker arranged as *Bam*HI-*Sall*-linker-nociceptin variant-*Nhe*I-spacer-*Spe*I-*Pst*II-*Xba*I-stop codon-*Hind*III (SEQ ID77). The final construct contains the LC-linker-nociceptin variant-spacer-H_N ORF sequences (SEQ ID78) for expression as a protein of the sequence illustrated in SEQ ID79. The fusion protein is termed CPNv-C (act. A). Figure 20 illustrates the purification of CPNv-C (act. A) from *E. coli* following the methods used in Example 26.

Example 35 - Assessment of *in vitro* efficacy of an LC/C-nociceptin variant-H_N/C fusion protein

Following the methods used in Example 26, the CPNv-C (act. A) prepared in Example 34 is obtained in a purified form and applied to the eDRG cell model to assess cleavage of SNAP-25 (using methodology from Example 30). After 24 h exposure to the fusion, 50% of maximal syntaxin cleavage is achieved by a fusion concentration of 3.1±2.0 nM. Figure 21 illustrates the cleavage of syntaxin following

24 h exposure of eDRG to CPNv-C (act. A).

Example 36 - Assessment of *in vivo* efficacy of an LC/A-nociceptin-HN/A fusion

5

The ability of an LC/A-nociceptin- H_N/A fusion (CPN/A) to inhibit acute capsaicin-induced mechanical allodynia is evaluated following subcutaneous intraplantar injection in the rat hind paw. Test animals are evaluated for paw withdrawal frequency (PWF%) in response to a 10 g Von Frey filament stimulus series (10 stimuli x 3 trials) prior to recruitment into the study, after subcutaneous treatment with CPN/A but before capsaicin, and following capsaicin challenge post-injection of CPN/A (average of responses at 15' and 30'). Capsaicin challenge is achieved by injection of 10 µL of a 0.3% solution. Sample dilutions are prepared in 0.5% BSA/saline. Figure 22 illustrates the reversal of mechanical allodynia that is achieved by pre-treatment of the animals with a range of concentrations of LC/A-nociceptin-HN/A fusion.

The ability of an LC/A-nociceptin-HN/A fusion (CPN/A) to inhibit streptozotocin (STZ)-induced mechanical (tactile) allodynia in rats is evaluated. STZ-induced mechanical allodynia in rats is achieved by injection of streptozotocin (i.p. or i.v.) which yields destruction of pancreatic β-cells leading to loss of insulin production, with concomitant metabolic stress (hyperglycemia and hyperlipidemia). As such, STZ induces Type I diabetes. In addition, STZ treatment leads to progressive development of neuropathy, which serves as a model of chronic pain with hyperalgesia and allodynia that may reflect signs observed in diabetic humans (peripheral diabetic neuropathy).

Male Sprague-Dawley rats (250-300 g) are treated with 65 mg/kg STZ in citrate buffer (I.V.) and blood glucose and lipid are measured weekly to define the readiness of the model. Paw Withdrawal Threshold (PWT) is measured in response to a Von Frey filament stimulus series over a period of time. Allodynia is said to be established when the PWT on two consecutive test dates (separated by 1 week)

measures below 6 g on the scale. At this point, rats are randomized to either a saline group (negative efficacy control), gabapentin group (positive efficacy control) or a test group (CPN/A). Test materials (20-25 μ l) are injected subcutaneously as a single injection (except gabapentin) and the PWT is measured at 1 day post-treatment and periodically thereafter over a 2-week period. Gabapentin (30 mg/kg i.p. @ 3 ml/kg injection volume) is injected daily, 2 hours prior to the start of PWT testing. Figure 23 illustrates the reversal of allodynia achieved by pre-treatment of the animals with 750 ng of CPN/A. Data were obtained over a 2-week period after a single injection of CPN/A

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Example 37 - Assessment of *in vivo* efficacy of an LC/A-nociceptin variant-H_N/A fusion

The ability of an LC/A-nociceptin variant-H_N/A fusion (CPNv/A) to inhibit capsaicin-induced mechanical allodynia is evaluated following subcutaneous intraplantar injection in the rat hind paw. Test animals are evaluated for paw withdrawal frequency (PWF%) in response to a 10 g Von Frey filament stimulus series (10 stimuli x 3 trials) prior to recruitment into the study (Pre-Treat); after subcutaneous intraplantar treatment with CPNv/A but before capsaicin (Pre-CAP); and following capsaicin challenge post-injection of CPNv/A (average of responses at 15' and 30'; CAP). Capsaicin challenge is achieved by injection of 10 μ L of a 0.3% solution. Sample dilutions are prepared in 0.5% BSA/saline.

Figure 24 illustrates the reversal of allodynia that is achieved by pre-treatment of the animals with a range of concentrations of LC/A-nociceptin variant-H_N/A fusion in comparison to the reversal achieved with the addition of LC/A-nociceptin-H_N/A fusion. These data are expressed as a normalized paw withdrawal frequency differential, in which the difference between the peak response (post-capsaicin) and the baseline response (pre-capsaicin) is expressed as a percentage. With this analysis, it can be seen that CPNv/A is more potent than CPN/A since a lower dose of CPNv/A is required to achieve similar analgesic effect to that seen with CPN/A.

Example 38 - Preparation of an LC/A-leu enkephalin-H_N/A fusion protein

Due to the small, five-amino acid, size of the leu-enkephalin ligand the LC/A-leu enkephalin-H_N/A fusion is created by site directed mutagenesis [for example using Quickchange (Stratagene Inc.)] using the LC/A-nociceptin-H_N/A fusion (SEQ ID39) as a template. Oligonucleotides are designed encoding the YGGFL leu-enkephalin peptide, ensuring standard *E. coli* codon usage is maintained and no additional restriction sites are incorporated, flanked by sequences complimentary to the linker region of the LC/A-nociceptin-H_N/A fusion (SEQ ID39) either side on the nociceptin section. The SDM product is checked by sequencing and the final construct containing the LC-linker-leu enkephalin-spacer-H_N ORF (SEQ ID80) for expression as a protein of the sequence illustrated in SEQ ID81. The fusion protein is termed CPLE-A. Figure 25 illustrates the purification of CPLE-A from *E. coli* following the methods used in Example 26.

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Example 39 – Expression and purification of an LC/A-beta-endorphin-H_N/A fusion protein

Following the methods used in Example 26, and with the LC/A-beta-endorphin-H_N/A fusion protein (termed CPBE-A) created in Example 24, the CPBE-A is purified from *E. coli*. Figure 26 illustrates the purified protein as analysed by SDS-PAGE.

20

Example 40 - Preparation of an LC/A-nociceptin mutant-H_N/A fusion protein

Due to the single amino acid modification necessary to mutate the nociceptin sequence at position 1 from a Phe to a Tyr, the LC/A-nociceptin mutant-H_N/A fusion is created by site directed mutagenesis [for example using Quickchange (Stratagene Inc.)] using the LC/A-nociceptin-H_N/A fusion (SEQ ID39) as a template. Oligonucleotides are designed encoding tyrosine at position 1 of the nociceptin sequence, ensuring standard *E. coli* codon usage is maintained and no additional restriction sites are incorporated, flanked by sequences complimentary to the linker region of the LC/A-nociceptin-H_N/A fusion (SEQ ID39) either side on the nociceptin

30

section. The SDM product is checked by sequencing and the final construct containing the LC/A-nociceptin mutant-spacer-H_N/A fusion ORF (SEQ ID82) for expression as a protein of the sequence illustrated in SEQ ID83. The fusion protein is termed CPOP-A. Figure 27 illustrates the purification of CPOP-A from *E. coli* following the methods used in Example 26.

Example 41 - Preparation and assessment of an LC/A-nociceptin variant mutant-H_N/A fusion protein

Due to the single amino acid modification necessary to mutate the nociceptin sequence at position 1 from a Phe to a Tyr, the LC/A-nociceptin variant mutant-H_N/A fusion is created by site directed mutagenesis [for example using Quickchange (Stratagene Inc.)] using the LC/A-nociceptin variant-H_N/A fusion (SEQ ID51) as a template. Oligonucleotides are designed encoding tyrosine at position 1 of the nociceptin sequence, ensuring standard *E. coli* codon usage is maintained and no additional restriction sites are incorporated, flanked by sequences complimentary to the linker region of the LC/A-nociceptin variant-H_N/A fusion (SEQ ID51) either side on the nociceptin section. The SDM product is checked by sequencing and the final construct containing the LC/A-nociceptin mutant-spacer-H_N/A fusion ORF (SEQ ID84) for expression as a protein of the sequence illustrated in SEQ ID85. The fusion protein is termed CPOPv-A. Figure 28 illustrates the purification of CPOPv-A from *E. coli* following the methods used in Example 26.

Using methodology described in Example 30, CPOPv-A is assessed for its ability to cleave SNAP-25 in the eDRG cell model. Figure 29 illustrates that CPOPv-A is able to cleave SNAP-25 in the eDRG model, achieving cleavage of 50% of the maximal SNAP-25 after exposure of the cells to approximately 5.9 nM fusion for 24 h.

Example 42 - Preparation of an IgA protease-nociceptin variant-H_N/A fusion protein

The IgA protease amino acid sequence was obtained from freely available database.

sources such as GenBank (accession number P09790). Information regarding the structure of the *N. Gonorrhoeae* IgA protease gene is available in the literature (Pohlner *et al.*, Gene structure and extracellular secretion of *Neisseria gonorrhoeae* IgA protease, *Nature*, 1987, 325(6103), 458-62). Using Backtranslation tool v2.0 (Entelechon), the DNA sequence encoding the IgA protease modified for *E. coli* expression was determined. A *Bam*HI recognition sequence was incorporated at the 5' end and a codon encoding a cysteine amino acid and *Sal*I recognition sequence were incorporated at the 3' end of the IgA DNA. The DNA sequence was screened using MapDraw, (DNASTAR Inc.) for restriction enzyme cleavage sequences incorporated during the back translation. Any cleavage sequences that are found to be common to those required for cloning were removed manually from the proposed coding sequence ensuring common *E. coli* codon usage is maintained. *E. coli* codon usage was assessed Graphical Codon Usage Analyser (Geneart), and the %GC content and codon usage ratio assessed by reference to published codon usage tables. This optimised DNA sequence (SEQ ID86) containing the IgA open reading frame (ORF) is then commercially synthesized.

The IgA (SEQ ID86) is inserted into the LC-linker-nociceptin variant-spacer-H_N ORF (SEQ ID51) using *Bam*HI and *Sal*I restriction enzymes to replace the LC with the IgA protease DNA. The final construct contains the IgA-linker-nociceptin variant-spacer-H_N ORF (SEQ ID87) for expression as a protein of the sequence illustrated in SEQ ID88.

Example 43 - Preparation and assessment of a nociceptin targeted endopeptidase fusion protein with a removable histidine purification tag.

DNA was prepared that encoded a Factor Xa removable his-tag (his6), although it is clear that alternative proteases site such as Enterokinase and alternative purification tags such as longer histidine tags are also possible. Using one of a variety of reverse translation software tools [for example EditSeq best *E. coli* reverse translation (DNASTAR Inc.), or Backtranslation tool v2.0 (Entelechon)], the DNA sequence encoding the Factor Xa removable his-tag region is determined.

Restriction sites are then incorporated into the DNA sequence and can be arranged as *NheI*-linker-*SpeI*-*PstI*-*H_N*/A-*XbaI*-LEIEGRSGHHHHHStop codon-*HindIII* (SEQ ID89). The DNA sequence is screened for restriction sequence incorporated and any additional sequences are removed manually from the remaining sequence ensuring common *E. coli* codon usage is maintained. *E. coli* codon usage is assessed by reference to software programs such as Graphical Codon Usage Analyser (Geneart), and the %GC content and codon usage ratio assessed by reference to published codon usage tables (for example GenBank Release 143, 13 September 2004). This optimised DNA sequence is then commercially synthesized (for example by Entelechon, Geneart or Sigma-Genosys) and is provided in the pCR 4 vector. In order to create CPNV-A-FXa-HT (SEQ ID90, removable his-tag construct) the pCR 4 vector encoding the removable his-tag is cleaved with *NheI* and *HindIII*. The *NheI* - *HindIII* fragment is then inserted into the LC/A-CPNV-*H_N*/A vector (SEQ ID51) that has also been cleaved by *NheI* and *HindIII*. The final construct contains the LC/A-linker-nociceptin variant-spacer-*H_N*-FXa-Histag-*HindIII* ORF sequences (SEQ ID90) for expression as a protein of the sequence illustrated in SEQ ID91. Figure 30 illustrates the purification of CPNV-A-FXa-HT from *E. coli* following the methods used in Example 26.

Example 44 - Preparation of a leu-enkephalin targeted endopeptidase fusion protein containing a translocation domain derived from diphtheria toxin

The DNA sequence is designed by back translation of the amino acid sequence of the translocation domain of the diphtheria toxin (obtained from freely available database sources such as GenBank (accession number 1XDTT) using one of a variety of reverse translation software tools [for example EditSeq best *E. coli* reverse translation (DNASTAR Inc.), or Backtranslation tool v2.0 (Entelechon)]. Restriction sites are then incorporated into the DNA sequence and can be arranged as *NheI*-Linker-*SpeI*-*PstI*- diphtheria translocation domain-*XbaI*-stop codon-*HindIII* (SEQ ID92). *PstI/XbaI* recognition sequences are incorporated at the 5' and 3' ends of the translocation domain respectively of the sequence maintaining the correct reading frame. The DNA sequence is screened using software such as MapDraw.

DNASTAR Inc.) for restriction enzyme cleavage sequences incorporated during the back translation. Any cleavage sequences that are found to be common to those required by the cloning system are removed manually from the proposed coding sequence ensuring common *E. coli* codon usage is maintained. *E. coli* codon usage is assessed by reference to software programs such as Graphical Codon Usage Analyser (Geneart), and the %GC content and codon usage ratio assessed by reference to published codon usage tables (for example GenBank Release 143, 13 September 2004). This optimised DNA sequence containing the diphtheria translocation domain is then commercially synthesized as *NheI*-Linker-*SpeI*-*PstI*-diphtheria translocation domain-*XbaI*-stop codon-*HindIII* (for example by Entelechon, Geneart or Sigma-Genosys) and is provided in the pCR 4 vector (Invitrogen). The pCR 4 vector encoding the diphtheria translocation domain is cleaved with *NheI* and *XbaI*. The *NheI* – *XbaI* fragment is then inserted into the LC/A-CPLE-H_N/A vector (SEQ ID80) that has also been cleaved by *NheI* and *XbaI*. The final construct contains the LC/A-leu-enkephalin-spacer-diphtheria translocation domain ORF sequences (SEQ ID93) for expression as a protein of the sequence illustrated in SEQ ID94.

Example 45 - Preparation of a nociceptin variant targeted endopeptidase fusion protein containing a LC domain derived from tetanus toxin.

The DNA sequence is designed by back translation of the tetanus toxin LC amino acid sequence (obtained from freely available database sources such as GenBank (accession number X04436) using one of a variety of reverse translation software tools [for example EditSeq best *E. coli* reverse translation (DNASTAR Inc.), or Backtranslation tool v2.0 (Entelechon)]. *BamHI*/*Sall* recognition sequences are incorporated at the 5' and 3' ends respectively of the sequence maintaining the correct reading frame (SEQ ID95). The DNA sequence is screened (using software such as MapDraw, DNASTAR Inc.) for restriction enzyme cleavage sequences incorporated during the back translation. Any cleavage sequences that are found to be common to those required by the cloning system are removed manually from the proposed coding sequence ensuring common *E. coli* codon usage is maintained. *E.*

coli codon usage is assessed by reference to software programs such as Graphical Codon Usage Analyser (Geneart), and the %GC content and codon usage ratio assessed by reference to published codon usage tables (for example GenBank Release 143, 13 September 2004). This optimised DNA sequence containing the

5 tetanus toxin LC open reading frame (ORF) is then commercially synthesized (for example by Entelechon, Geneart or Sigma-Genosys) and is provided in the pCR 4 vector (invitrogen). The pCR 4 vector encoding the TeNT LC is cleaved with *Bam*HI and *Sa*II. The *Bam*HI – *Sa*II fragment is then inserted into the LC/A-CPNv-H_N/A vector (SEQ ID51) that has also been cleaved by *Bam*HI and *Sa*II. The final

10 construct contains the TeNT LC-linker-nociceptin variant-spacer-H_N ORF sequences (SEQ ID96) for expression as a protein of the sequence illustrated in SEQ ID97.

Example 46 - Preparation of an LC/C-nociceptin variant-H_N/C fusion protein with a native serotype C linker that is susceptible to Factor Xa cleavage

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Following the methods used in Example 21, the LC/C (SEQ ID31) and H_N/C (SEQ ID32) are created and inserted into the C serotype nociceptin variant linker arranged as *Bam*HI-*Sa*II-linker-nociceptin variant-*Nhe*I-spacer-*Spe*I-*Pst*II-*Xba*I-stop codon-*Hind*III (SEQ ID98). The final construct contains the LC-linker-nociceptin variant-

20 spacer-H_N ORF sequences (SEQ ID99) for expression as a protein of the sequence illustrated in SEQ ID100. The fusion protein is termed CPNv-C (act. C).

25

Claims

1. Use of a therapeutic molecule for the manufacture of a medicament for the treatment of a particular type of pain, wherein the therapeutic molecule is a
5 non-cytotoxic protein conjugate that binds to a nociceptive sensory afferent cell, and comprises:

(i) Targeting Moiety (TM),

10 wherein said TM is an agonist of a receptor present on said nociceptive sensory afferent cell, and wherein said receptor undergoes endocytosis to be incorporated into an endosome within the nociceptive sensory afferent cell;

15 (ii) a non-cytotoxic protease or a fragment thereof,

wherein the protease or protease fragment is capable of cleaving a protein of the exocytic fusion apparatus of said nociceptive sensory afferent cell; and

20

(iii) a Translocation Domain,

wherein the Translocation Domain translocates the protease or protease fragment from within the endosome, across the
25 endosomal membrane, and into the cytosol of the nociceptive sensory afferent cell.

2. Use of Claim 1, wherein the receptor is an ORL₁ receptor.

30 3. Use of Claim 1 or 2, wherein the TM has at least 70% or at least 80 % homology to SEQ ID No. 2 or a fragment thereof.

4. Use of Claim 1 or 2, wherein the TM has at least 90% homology to SEQ ID No. 2 or a fragment thereof.
- 5 5. Use of Claim 1 or Claim 2, wherein the TM has at least 95% homology to SEQ ID No. 2 or a fragment thereof.
6. Use of Claim 1 or 2, wherein the TM is SEQ ID No. 2 or a fragment thereof.
- 10 7. Use of Claim 1 or 2, wherein the TM is nociceptin.
8. Use of Claim 1 or 2, wherein the TM is selected from the group consisting of SEQ ID Nos. 4, 6, 8, 10, 12, 14.
- 15 9. Use of any preceding claim, wherein the non-cytotoxic protease is a bacterial protein, or a fragment thereof, capable of cleaving a protein of the exocytic fusion apparatus of the nociceptive sensory afferent cell.
10. Use of Claim 9, wherein the non-cytotoxic protease is selected from a
20 clostridial neurotoxin, or an IgA protease.
11. Use of any preceding claim, wherein the Translocation Domain is derived from a clostridial source.
- 25 12. Use of Claim 11, wherein the Translocation Domain is a botulinum H_N domain.
13. Use of any preceding claim, wherein the nociceptive sensory afferent cell is a primary nociceptive sensory afferent cell.
- 30 14. Use according to Claim 1, wherein said conjugate comprises an amino acid

sequence selected from the group consisting of SEQ ID NOs 14, 16, 18, 20, 22, 24, and 26.

- 5 15. Use of a therapeutic molecule for the manufacture of a medicament for the treatment of a particular type of pain, wherein the therapeutic molecule is a non-cytotoxic conjugate that binds to a nociceptive sensory afferent cell, and comprises:

10 (i) a Targeting Moiety (TM),

wherein said TM is an agonist of a receptor present on said nociceptive sensory afferent cell, and wherein said receptor undergoes endocytosis to be incorporated into an endosome within the nociceptive sensory afferent cell;

15 (ii) a DNA sequence encoding a non-cytotoxic protease or a fragment thereof,

20 wherein the DNA sequence is expressible in the nociceptive sensory afferent cell and when so expressed provides a protease or protease fragment capable of cleaving a protein of the exocytic fusion apparatus of said nociceptive sensory afferent cell; and

25 (iii) a Translocation Domain,

30 wherein the Translocation Domain translocates the DNA sequence encoding the protease or protease fragment from within the endosome, across the endosomal membrane, and into the nociceptive sensory afferent cell.

16. Use of Claim 15, wherein the receptor is an GRL₁ receptor.

17. Use of Claim 15 or 16, wherein the TM has at least 70% or at least 80% homology to SEQ ID No. 2 or a fragment thereof.
- 5 18. Use of Claim 15 or 16, wherein the TM has at least 90% homology to SEQ ID No. 2 or a fragment thereof.
19. Use of Claim 15 or Claim 16, wherein the TM has at least 95% homology to SEQ ID No. 2 or a fragment thereof.
- 10 20. Use of Claim 15 or Claim 16, wherein the TM is SEQ ID No. 2 or a fragment thereof.
21. Use of Claim 15 or Claim 16, wherein the TM is nociceptin.
- 15 22. Use of Claim 15 or Claim 16, wherein the TM is selected from the group consisting of SEQ ID Nos. 4, 6, 8, 10, 12, 14.
23. Use of Claim 15 or Claim 16, wherein the non-cytotoxic protease is a
20 bacterial protein, or a fragment thereof, capable of cleaving a protein of the exocytic fusion apparatus of the nociceptive sensory afferent cell.
24. Use of Claim 23, wherein the non-cytotoxic protease is selected from a clostridial neurotoxin, or an IgA protease.
- 25 25. Use of Claim 15 or Claim 16, wherein the Translocation Domain is derived from a clostridial source.
26. Use of Claim 25, wherein the Translocation Domain is a botulinum H_N
30 domain.

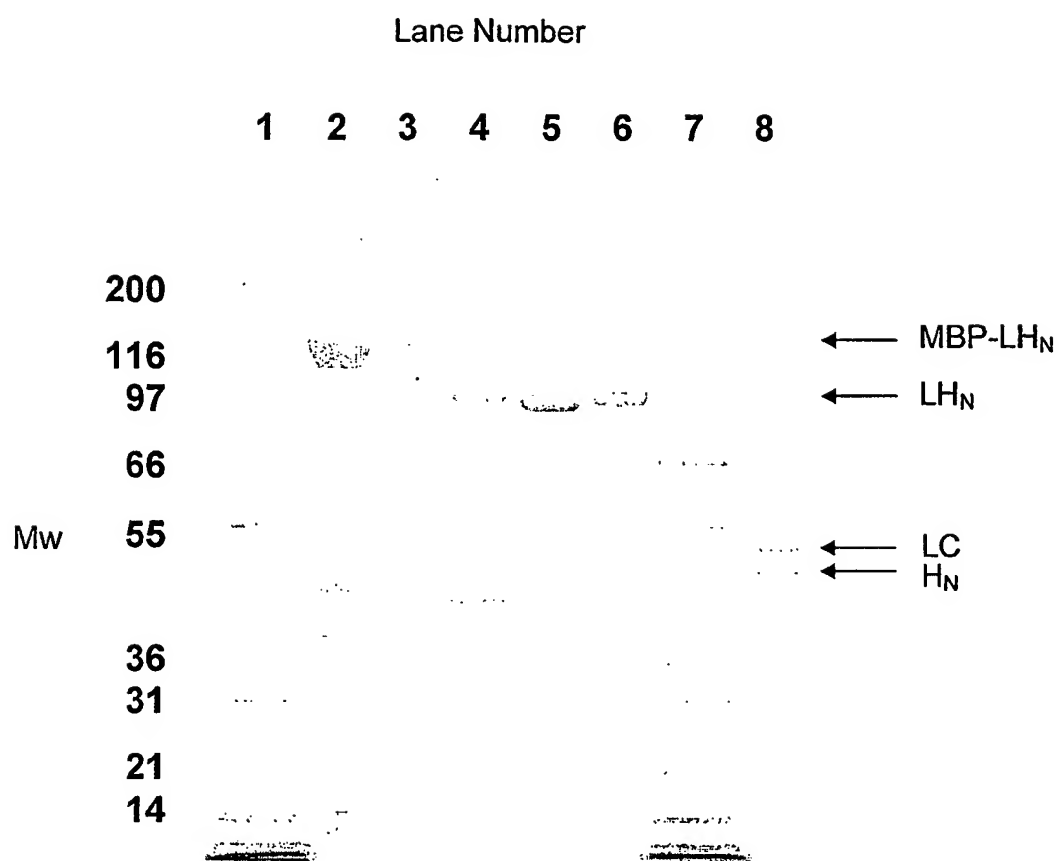
27. Use of Claim 15 or 16, wherein the nociceptive sensory afferent cell is a

primary nociceptive sensory afferent cell.

28. Use of any of Claims 1 to 14, wherein the TM, the Translocation Domain and the protease or fragment thereof are covalently linked.
- 5 29. Use of any of Claims 15 to 27, wherein the TM, the Translocation Domain and the DNA sequence encoding the protease or fragment thereof, are covalently linked.
- 10 30. Use according to any preceding claim, wherein the conjugate is present as a pharmaceutical composition, comprises a pharmaceutically acceptable carrier.
- 15 31. A method for treating a particular type of pain, comprising administering to a patient an effective amount of a conjugate as defined in any of Claims 1-30.

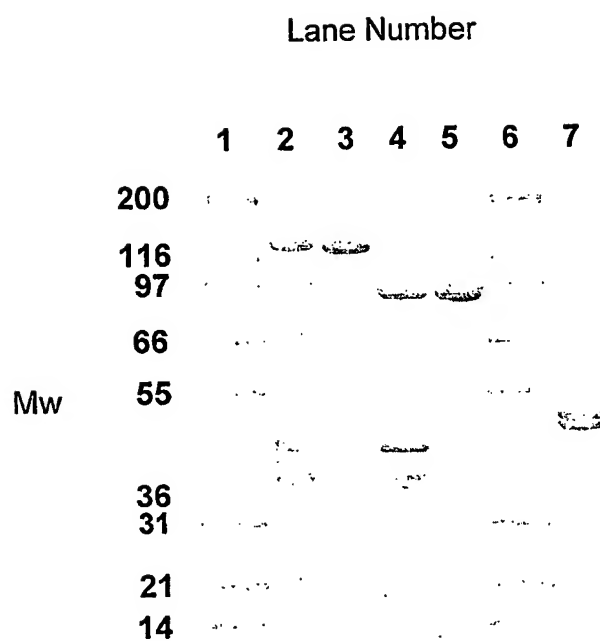
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Figure 1



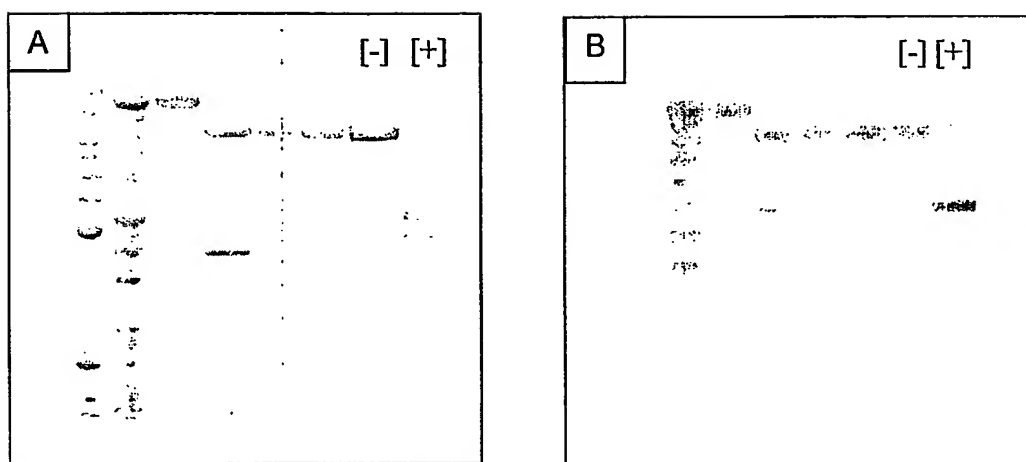
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Figure 2



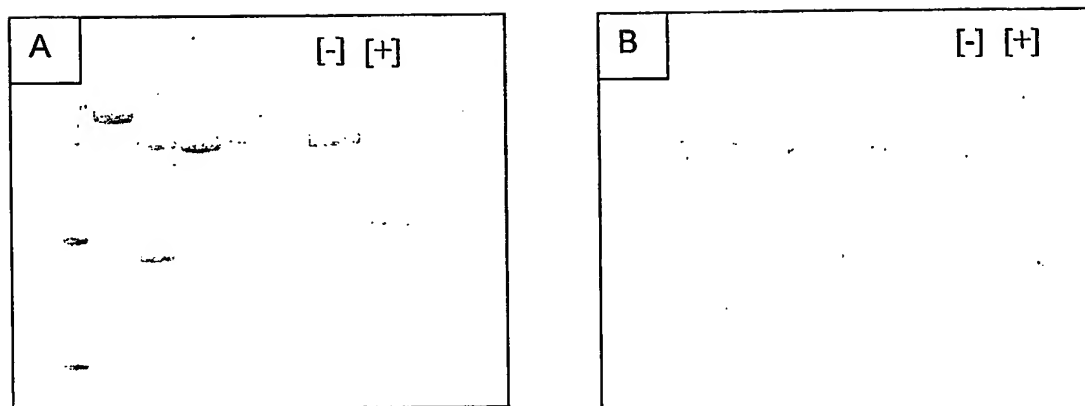
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Figure 3



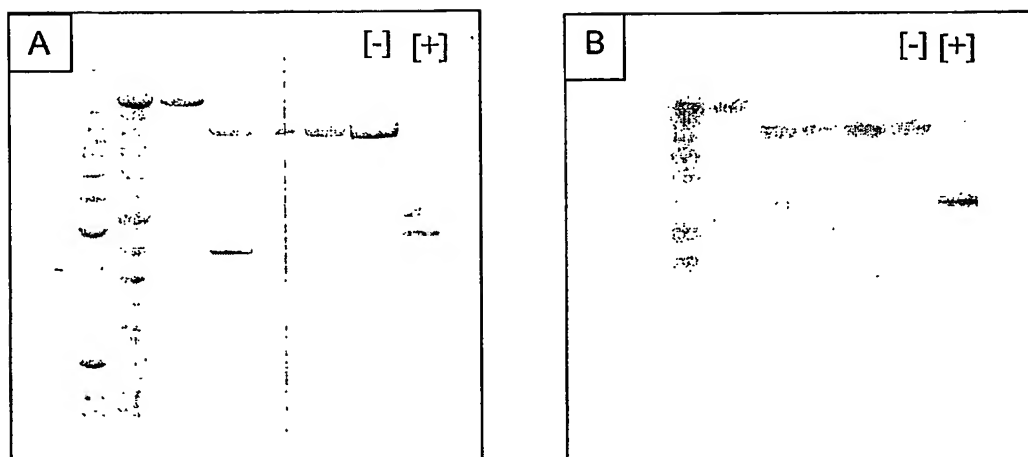
4/32

Figure 4



5/32

Figure 5



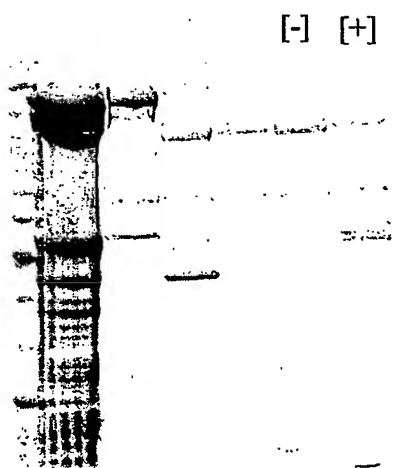
6/32

Figure 6



7/32

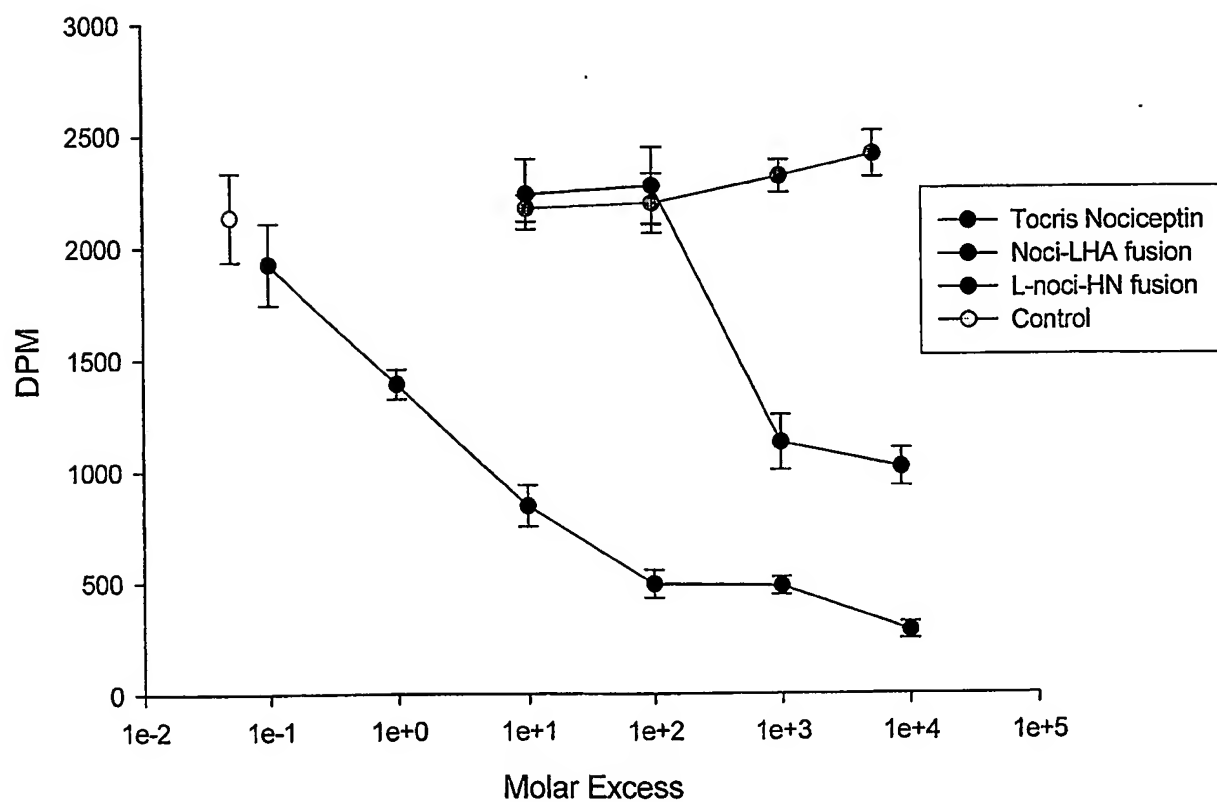
Figure 7



8/32

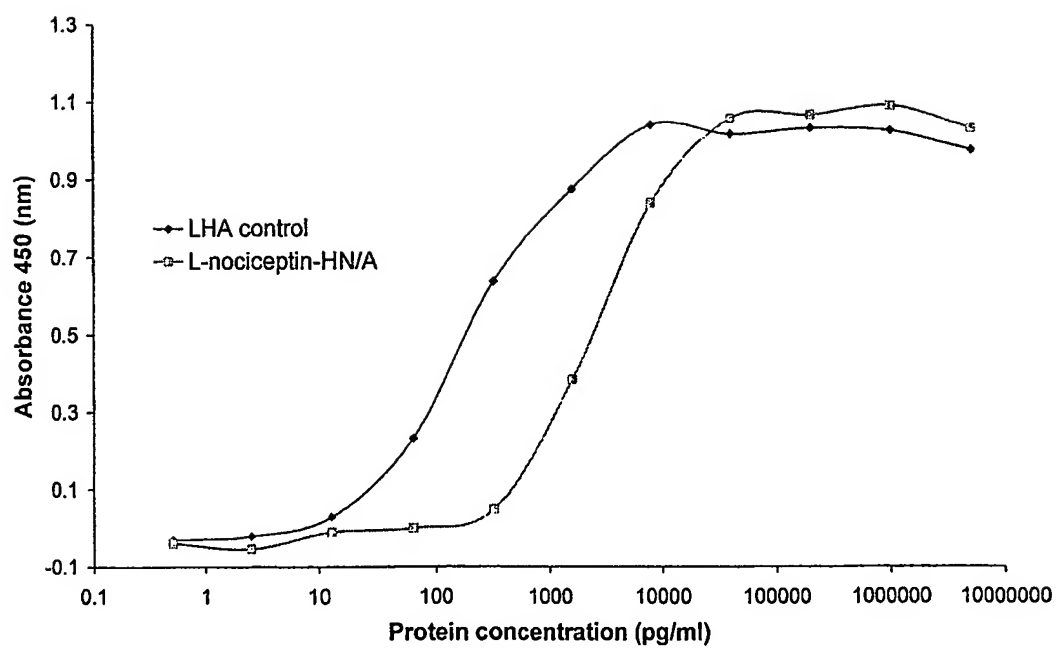
Figure 8

Competition Assay : Nociceptin-LH_N/A Fusions
vs 1nM [³H]-Nociceptin on eDRGs (4°C)



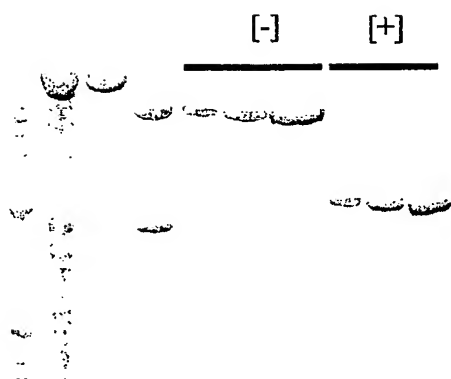
9/32

Figure 9



10/32

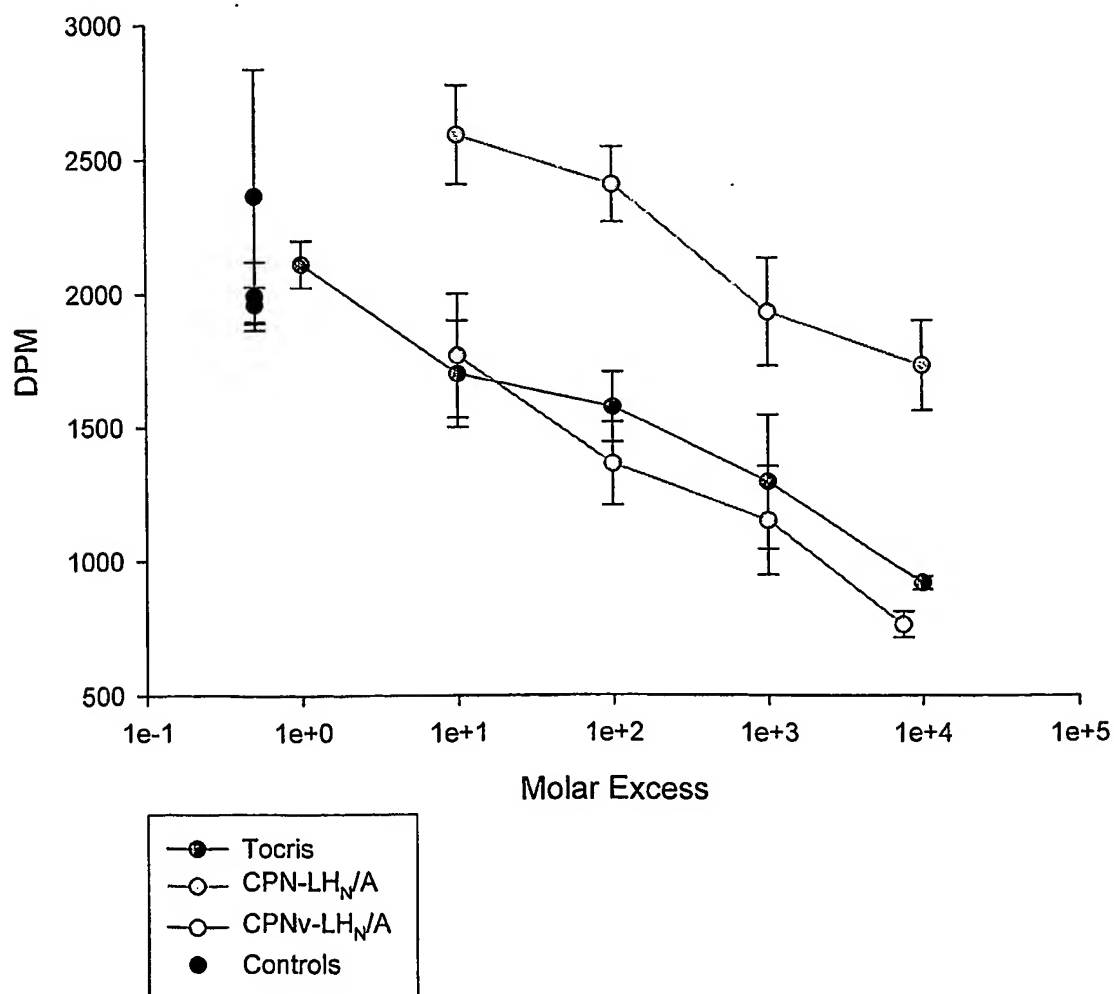
Figure 10



11/32

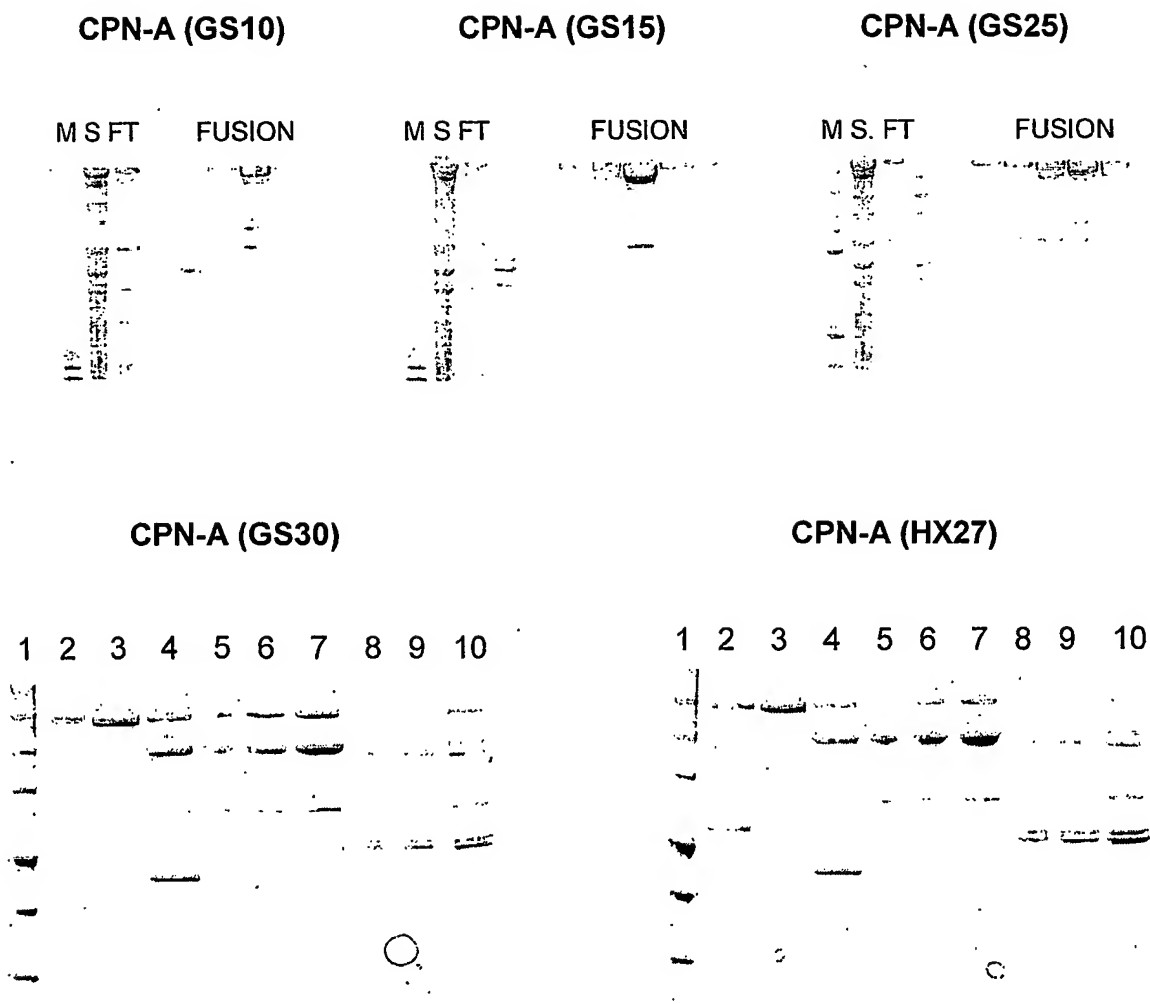
Figure 11

Competition Assay: CPN fusions vs 1nM [3H] - Nociceptin
on eDRGs for 1 hour at 4°C



12/32

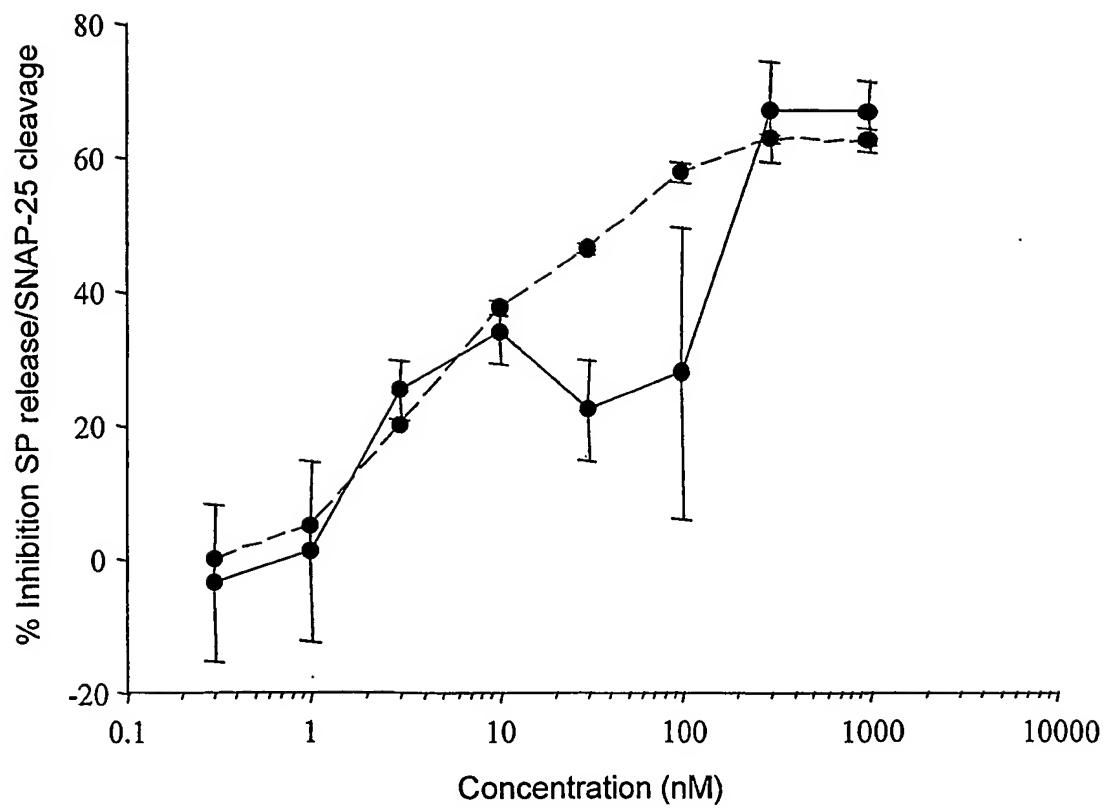
Figure 12



13/32

Figure 13

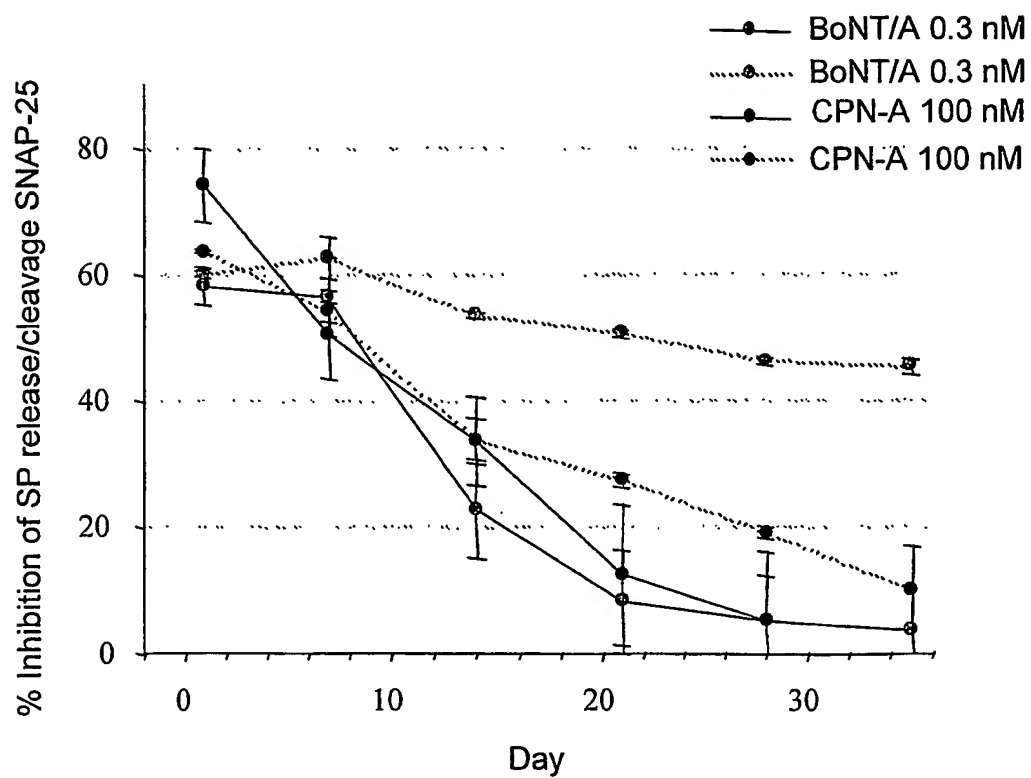
CPN-A on eDRG for 1 Day



14/32

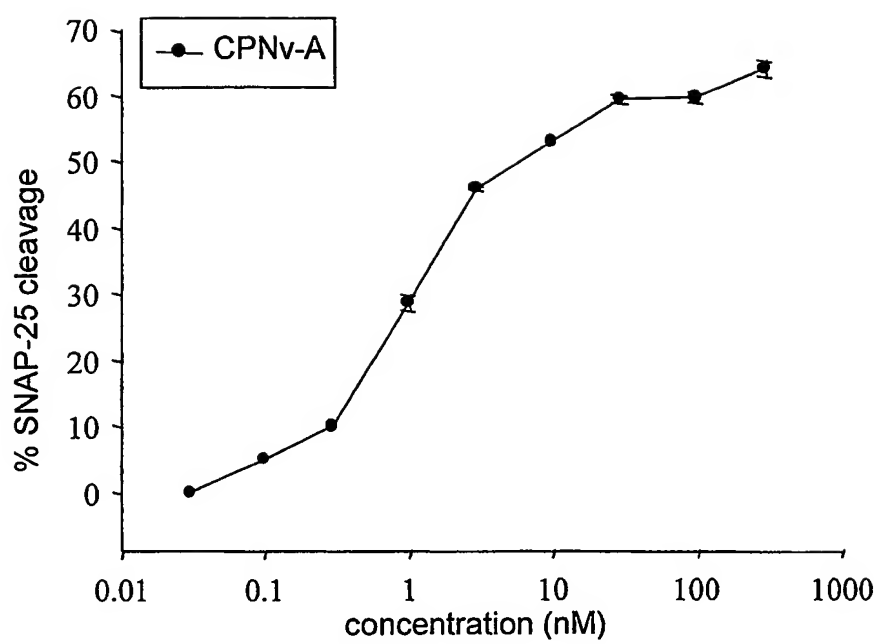
Figure 14

Duration of action following eDRG exposure for 1 Day



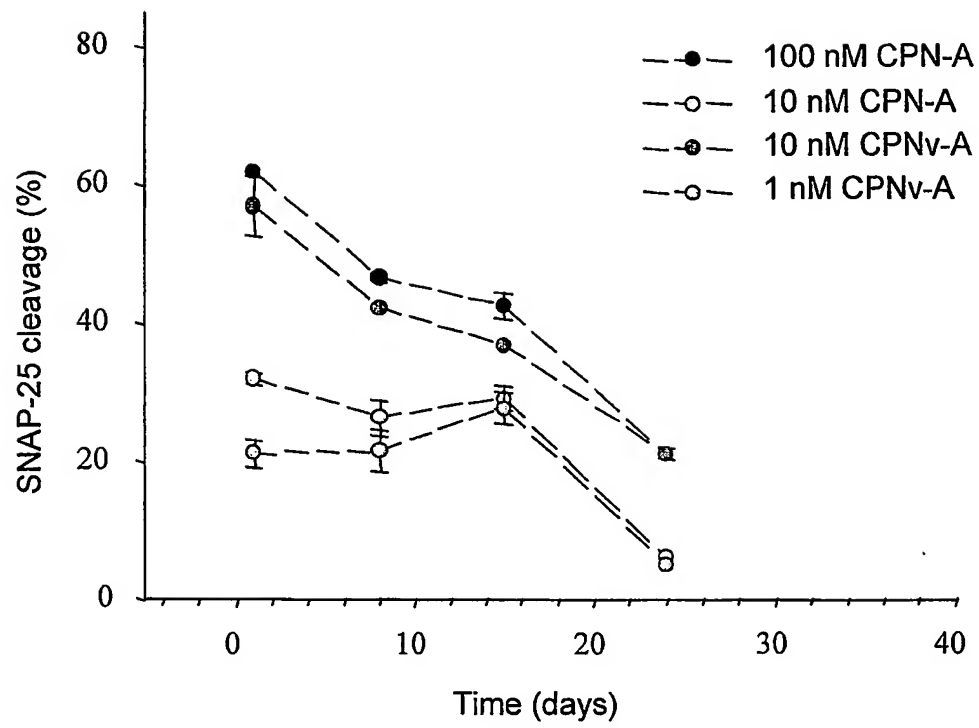
15/32

Figure 15



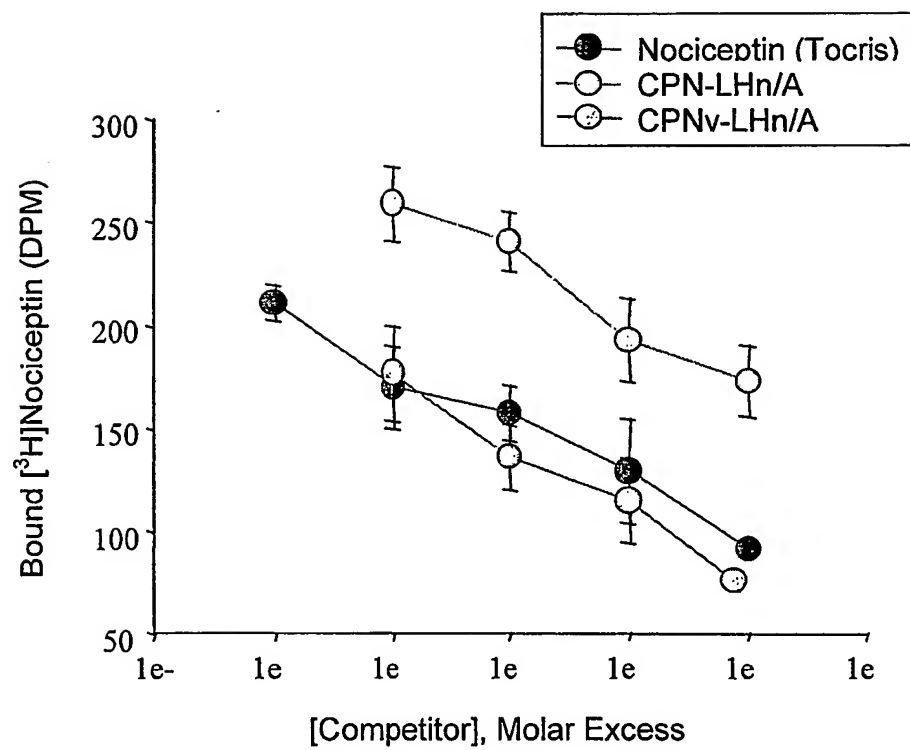
16/32

Figure 16



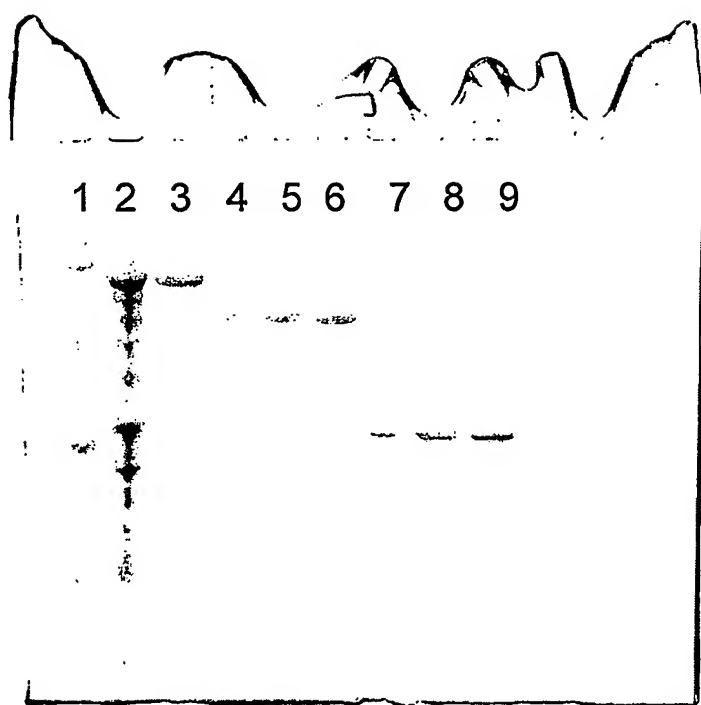
17/32

Figure 17



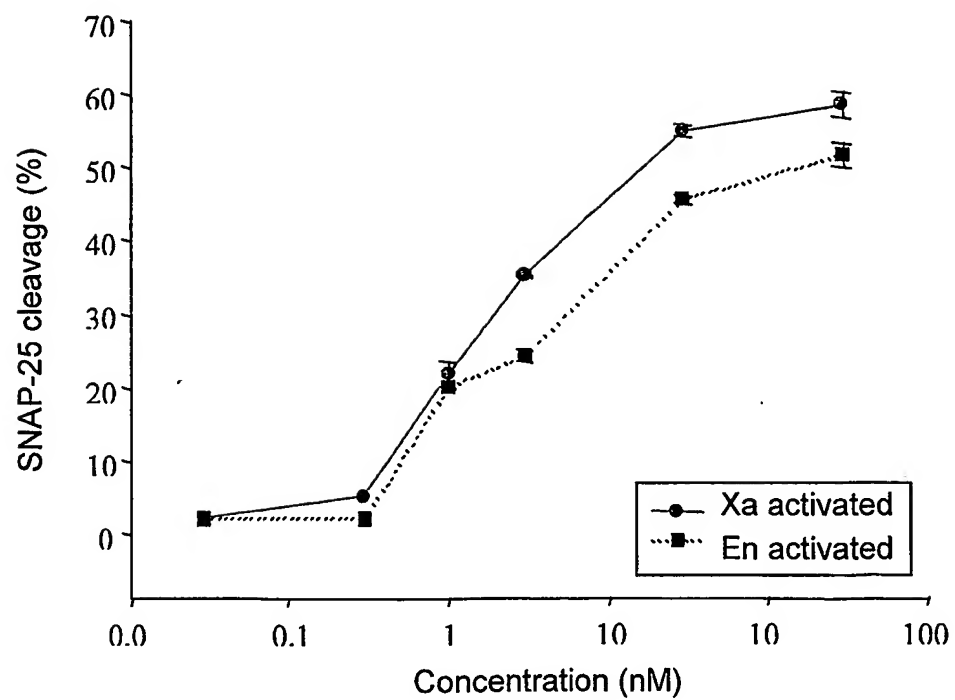
18/32

Figure 18



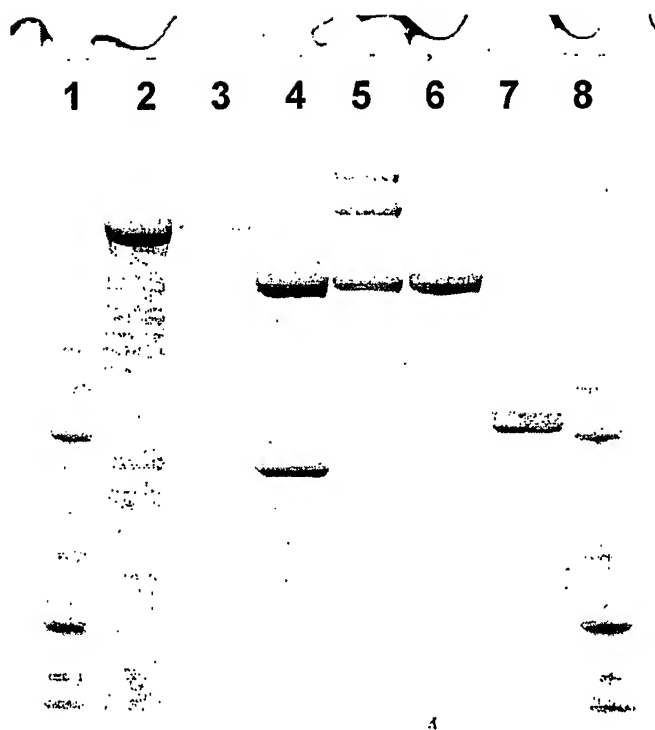
19/32

Figure 19



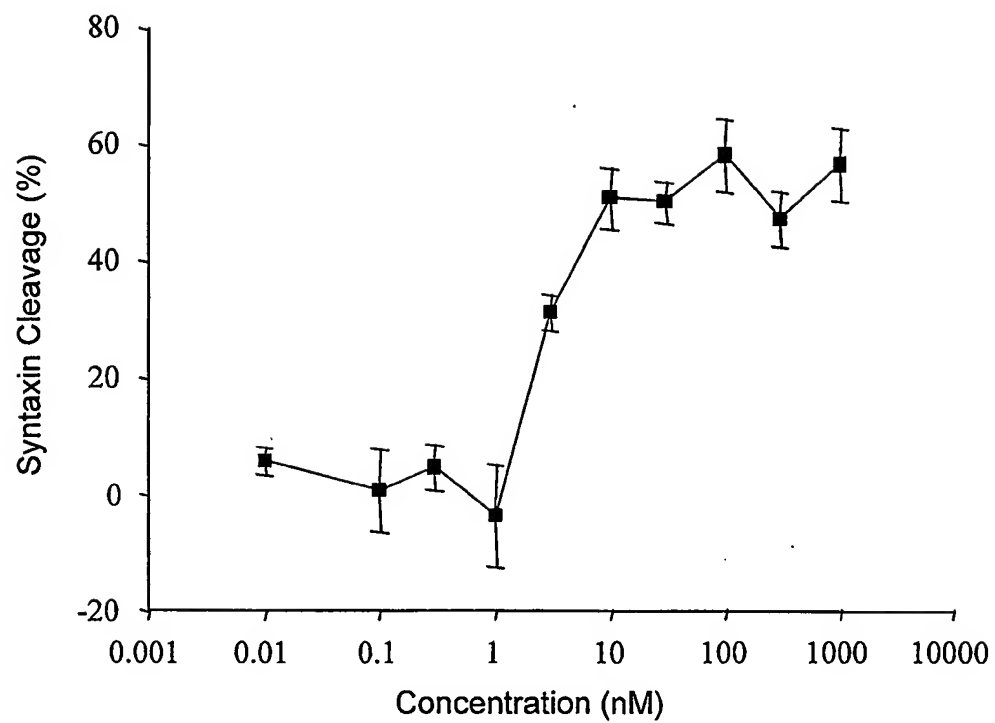
20/32

Figure 20



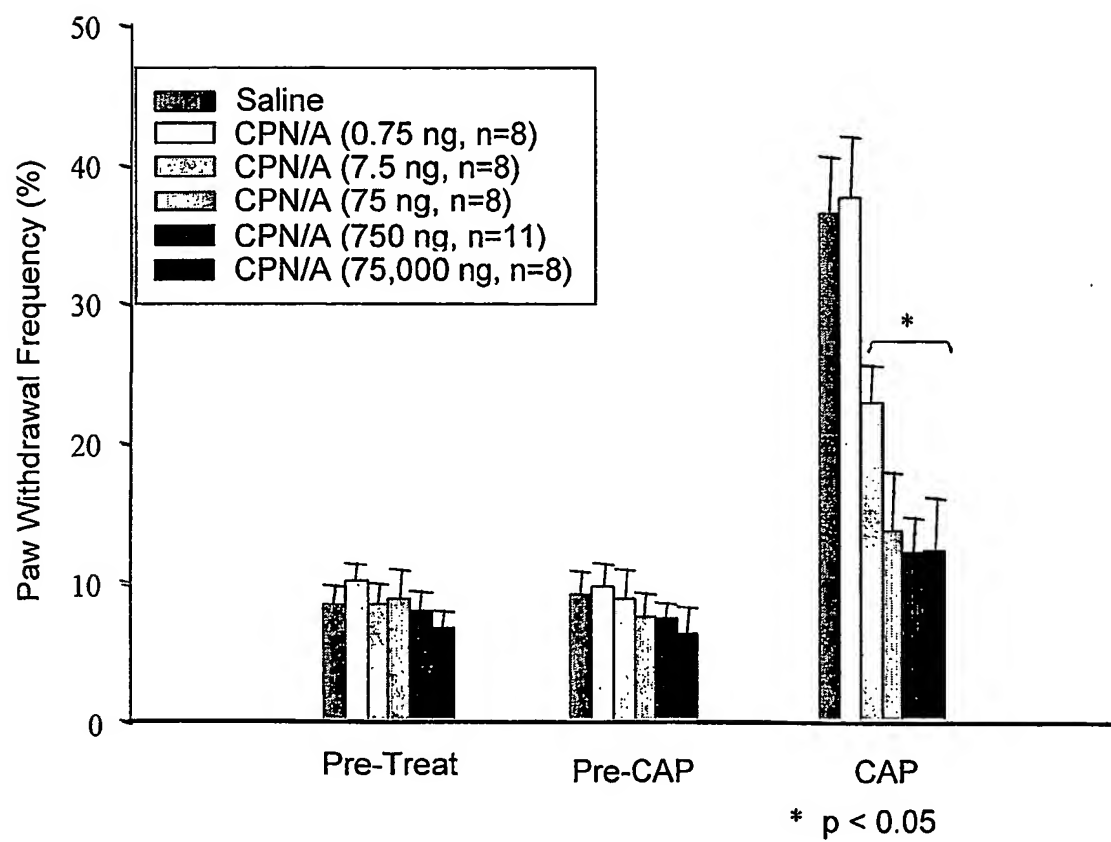
21/32

Figure 21



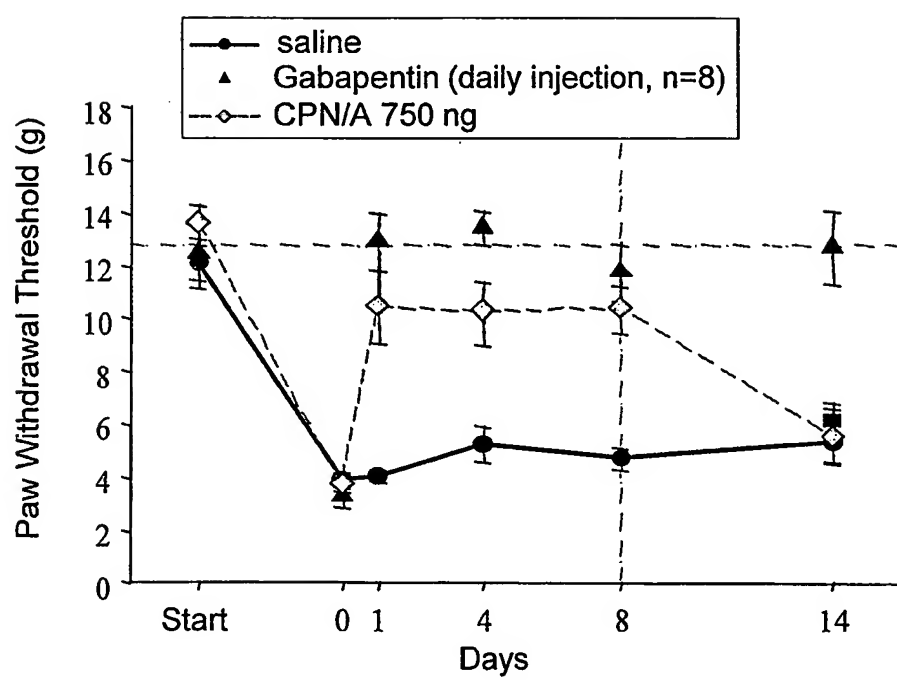
22/32

Figure 22



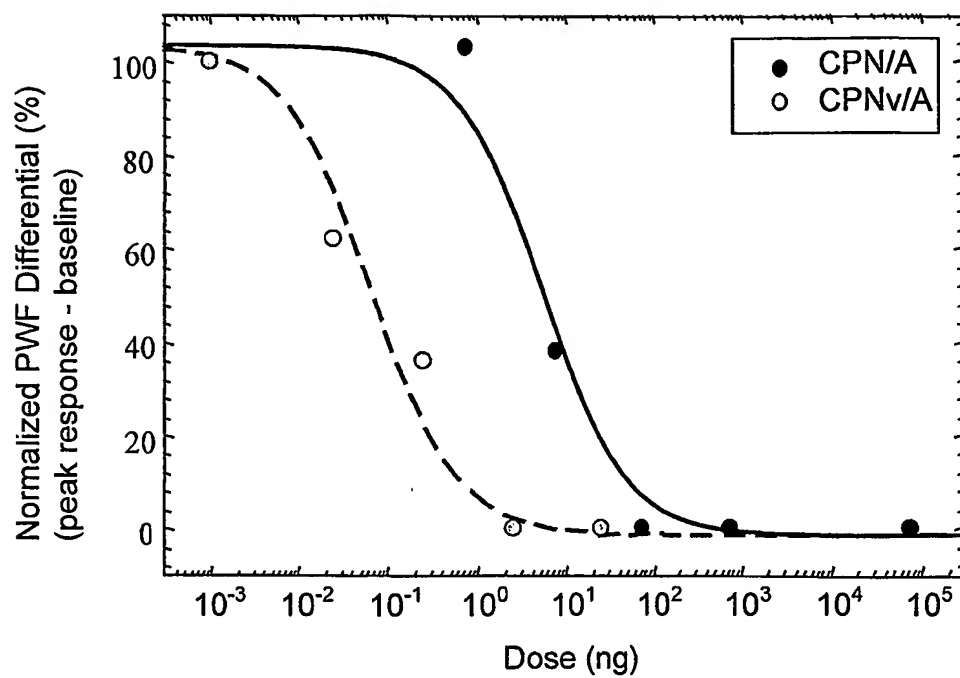
23/32

Figure 23



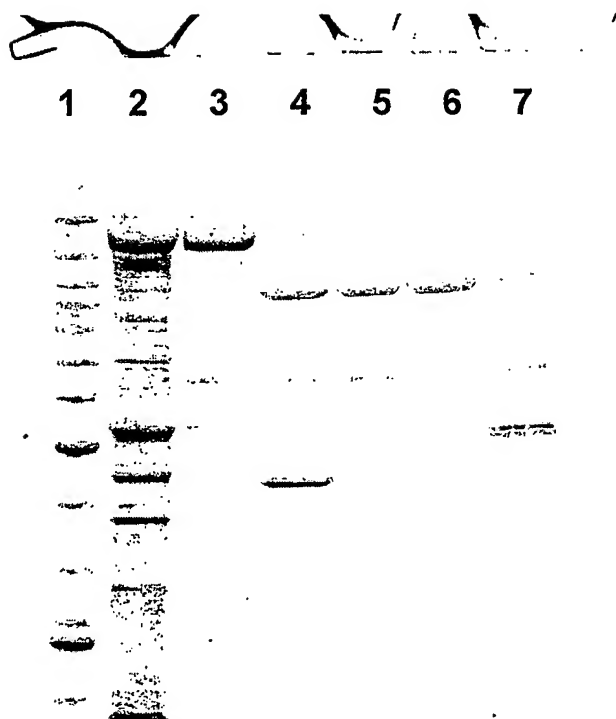
24/32

Figure 24



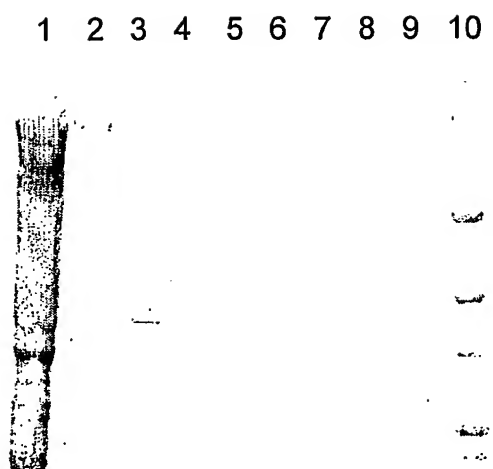
25/32

Figure 25



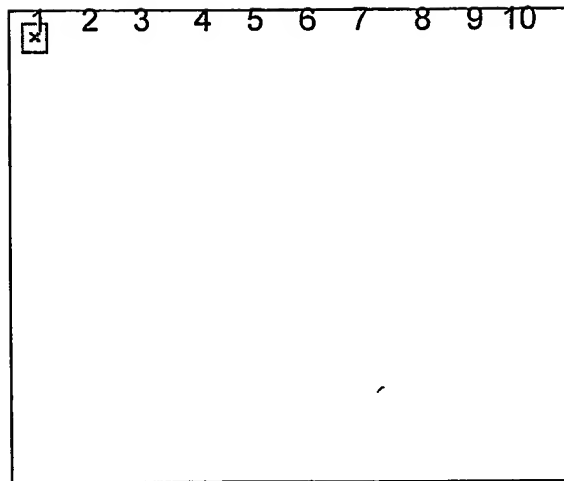
26/32

Figure 26



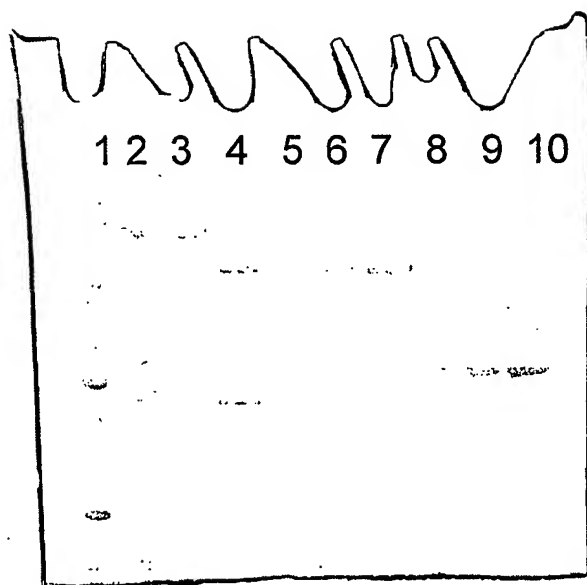
27/32

Figure 27



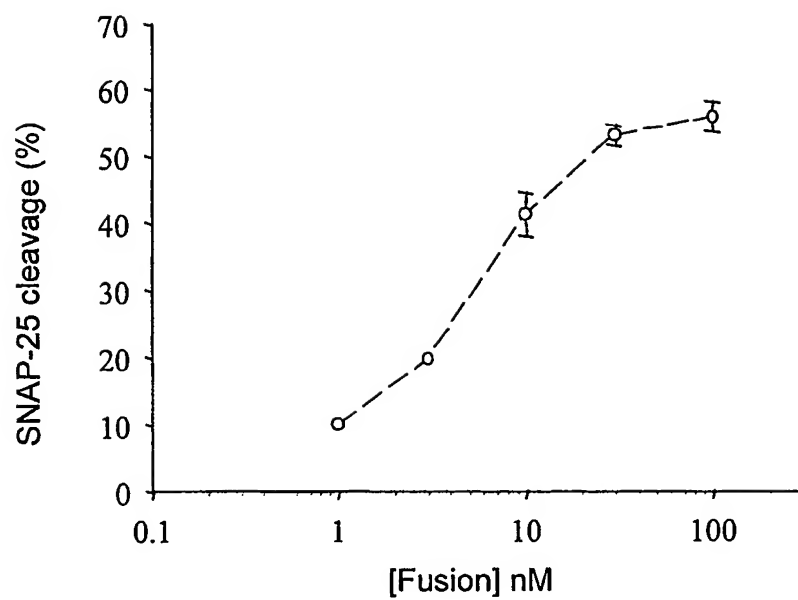
28/32

Figure 28



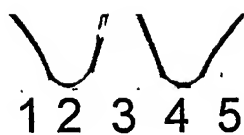
29/32

Figure 29



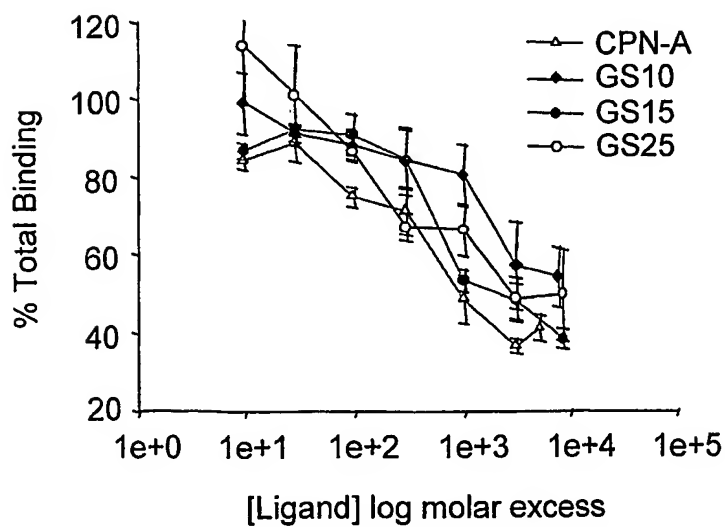
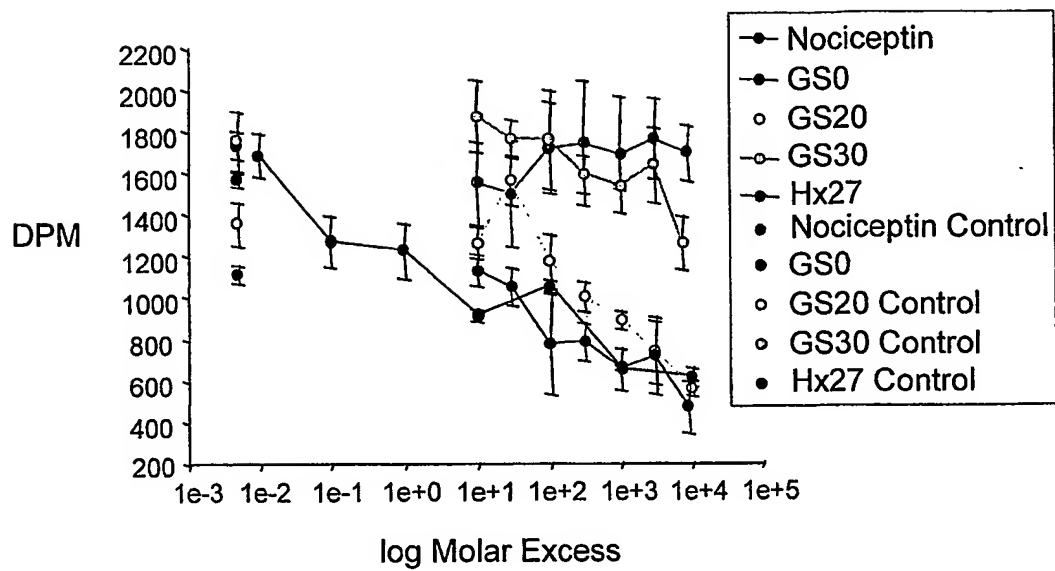
30/32

Figure 30



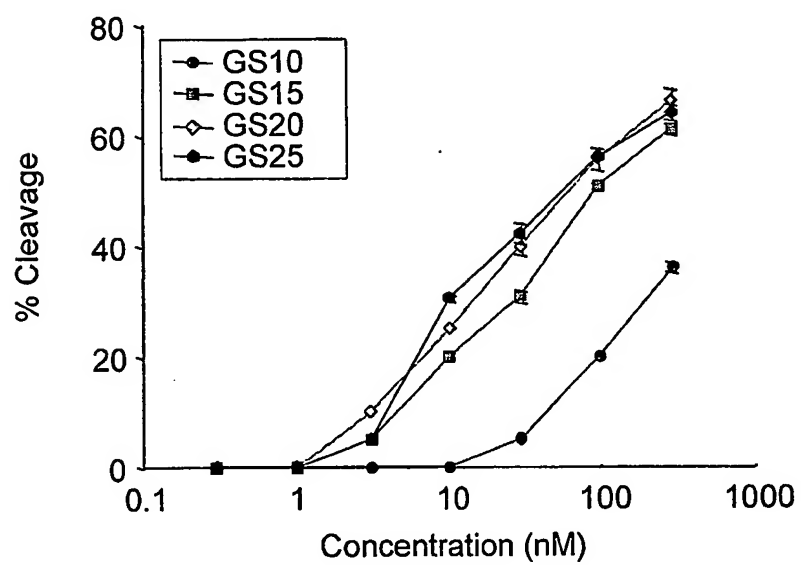
31/32

Figure 31



32/32

Figure 32



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- ☒ **LINES OR MARKS ON ORIGINAL DOCUMENT**
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